BX
.j
27.

Final Report of Dr. J. Walter Leather, F.I.C.,F.C.S., Agricultural Chemist to the Government of India.

B.X
J
27

00110457

ADM
354.50954
Lea / Fin
110457

ADM
354.50954
Lea (Fin
110457

Digitized with financial assistance from
Shri Brihad Bhartiya Samaj
on 31 October, 2019

FROM

DR. J. WALTER LEATHER, F.I.C.F.C.S.,
Agricultural Chemist to the Government of India,

TO

THE SECRETARY TO THE GOVERNMENT OF INDIA,
DEPARTMENT OF REVENUE AND AGRICULTURE.

Dated, Dehra Dun, the 1st November 1897.

SIR,

110457

IN compliance with the instructions conveyed in your letter No. 606—49-2, dated 1st May 1897, I have the honour to submit to you herewith the Report on the work on which I have been engaged during the period (five years) in which I have had the honour to hold the appointment of Agricultural Chemist.

2. The Report is divided into chapters, the arrangement of which as regards subject-matter corresponds generally to that adopted by Dr. Voelcker in his Report.

3. The work upon which I have been engaged may be divided under the following heads: (*a*) advising on the work generally which is carried on at the Experimental Farms, and the institution of new experiments there; (*b*) the investigation of special subjects such as soils and sugarcane; (*c*) the examination of the students at several of the Agricultural Schools in Agriculture and Chemistry.

4. In carrying out this work I have spent a considerable part of each year in touring, and a list of these tours, with their objects, is attached to the Report as an Appendix No. I.

5. In setting out the results of my operations I have dealt with them as briefly as circumstances would admit.

Had the result of all my enquiries been already published, the Report would have become simply a *resumé* of this matter. In some cases this is possible. My investigations on usar land, on sugarcane, on certain well waters in Gujarat, have been published in the Agricultural Ledger, and a brief *resumé* of them was all that appeared necessary.

In other cases, however, the work was incomplete, and I should not have published the results at the present time. The information which I have obtained in regard to the various fodders, for instance, is not only very limited, but the number of samples was small, their selection not made in that systematic manner that I should have adopted had I been studying them more exhaustively, and the one or two comparative experiments with fodders referred to, require repeating in order to confirm the first results.

The results of my investigations into the composition of Indian soils are also dealt with in detail. These will be submitted for publication in the Agricultural Ledger separately before I leave India. It had been my intention to write a text-book on Indian soils, but want of time has prevented this.

6. Respecting the Experimental Farms, I have left more or less unaltered those experiments which appeared to be likely to provide useful information, even though they admitted of improvement. Field experiments usually occupy so long a time for their completion, and eventually leave the several plots of land in such an uneven condition, that unnecessary change was to be deprecated.

New experiments have been introduced as circumstances would admit. The latter, however, are confined to somewhat narrow limits, since it was impossible for me to attempt to study more than one or two of the principal crops.

There was room, at several of the farms, for improvement in the supervision. Far too little *direct* care and control had been given to the field experiments, and, for example, at the first farm I visited I found both the method of weighing crops, as well as the scales, incorrect. The supervision at several of the farms has been improved. Unfortunately there seems to be a peculiar weakness with the native of India for the system of giving an instruction in writing and leaving the execution of the details with too little further supervision. Agricultural experiments have been, and I fear still are in some cases, carried on in this manner. It is hopeless, however, to expect accuracy under such circumstances. Only this week a report was submitted to me for criticism, which contained such mistakes as to show that it could not have been even read by the agriculturist attached to the Department. However, as agricultural work in India expands, it may be anticipated that a larger call will be experienced for men of good education for this work, and accuracy of detail will be the more readily secured.

7. My duties in connection with Agricultural Education have been limited to the position of Examiner for three years at three of the Agricultural Schools.

Generally, I consider that the work attempted at present is well done. But there is a great want of good Agricultural text-books, and this want should be supplied as soon as possible.

I have the honour to be,

SIR,

Your most obedient Servant,

J. WALTER LEATHER,

Agricultural Chemist to the Government of India.

LIST OF CONTENTS.

PAGE

CHAPTER I.

Soils 1

CHAPTER II.

Water 43

CHAPTER III.

Manures 49

CHAPTER IV.

Wood fuel 58

CHAPTER V.

Implements 60

CHAPTER VI.

Hay and fodder crops 66

CHAPTER VII.

Crops and cultivation 70

CHAPTER VIII.

Agricultural industries 83

CHAPTER IX.

Practical enquiry 84

CHAPTER X.

Experimental farms 87

CHAPTER XI.

Agricultural education 117

APPENDIX I.

List of tours i

APPENDIX II.

List of papers and reports i

Final Report of Dr. J. Walter Leather, F.I.C., F.C.S., Agricultural Chemist to the Government of India.

CHAPTER I.

Soils.

General.—A considerable part of my time has been devoted to investigations on Indian soils.

This subject was dealt with by Dr. Voelcker in Chapter 5 of his Report, and the following matters are there discussed: (*a*) the composition of Indian soils; (*b*) the possible exhaustion of Indian soils; (*c*) the supply of nitrogen to Indian soils by rain and leguminous plants; (*d*) the reclamation of certain lands which have become infected by *kans* grass, eroded by surface drainage, or infertile from the presence of salts of sodium, called *reh*.

Of these four subjects I have attempted to deal with (*a*) the composition of Indian soils and (*d*) the reclamation of lands, more particularly those which suffer from the presence of *reh*. The subject (*b*), the exhaustion of Indian soils, is one which cannot be experimentally dealt with in any short period, such as that which I have had an opportunity of spending in India. I may, however, be permitted to discuss the matter briefly. The subject (*c*), the supply of nitrogen by rain or by leguminous plants, is one which might have been at least commenced, and it has only been left undone, because I found it quite impossible, under the circumstances of time and lack of qualified assistance, to pretend to do it properly. It will be apparent that either of these subjects would require the attention of a thoroughly qualified chemist *all the year round*, and this it has not been possible to provide.

In the present chapter therefore the composition of Indian soils, and the subjects of usar and ravine lands, will be dealt with, to which a brief paragraph on the exhaustion of Indian soils will be added.

The composition of Indian soils.

2. In the opening paragraph of his chapter on soils, Dr. Voelcker writes:—

"The soils of India have not so far been made the subject of careful or scientific study. A few analyses are recorded of the soils of particular spots and on two of the Government Experimental Farms a practical analysis of the soil has been attempted by growing crops on them ..... Such experiments have a certain value it is true .....but they fall far short of what may be gained by a systematic and scientific enquiry."

Again, in paragraph 419, among the subjects which Dr. Voelcker recommends as suitable for investigation by an agricultural chemist is "the sufficiencies and deficiencies of different soils in respect of the various soil constituents." Finally, in paragraph 424, Dr. Voelcker suggests that the agricultural chemist might usefully "assist the spread of agricultural education by the preparation of simple text-books."

It was, indeed, more with a view to trying to fulfil the latter recommendtion, than anything else, that I obtained, through some of the Local Governments and others samples of typical soils and have subjected them to chemical analysis.

The completion of this work has been delayed through other duties longer than I had at first anticipated, and the text-book which I had hoped to prepare before the close of the present year will not have been written.

The outcome of the work is nevertheless a fairly accurate knowledge of the composition of certain types of Indian soils, and considering the almost total absence of any information on the subject and the need there is for it as an aid to the lecturers in the several Agricultural Colleges and Schools, the matter contained in the present chapter will, I doubt not, prove itself of some assistance.

Besides exhibiting the general composition of the certain classes of soils to be referred to, I have been able, I believe, to explain satisfactorily the cause of the colour of the "black cotton soils" (*regur*) which has been the subject of some little speculation.

3. *Types of soils.*—As pointed out in paragraph 45 of Dr. Voelcker's Report, the number of main types of soils in India is far smaller, and their position geographically far more readily defined, than is the case with those in England, and although the variations are greater than is suggested by a mere glance at the Geological Map of India, it is nevertheless true that one may divide the principal soils of this vast peninsula, which approaches the area of Europe, under about four chief heads, the soils of which are each so perfectly distinct in colour and texture from one another, and stretch uninterruptedly over such very large areas, that such a classification is not only admissible, but essential. It is not, indeed, merely a matter of distinguishing clays from loams and sandy soils or marls, for each of the principal Indian types of soils includes those which are more clayey and those which contain much sand or gravel, but one rather of distinguishing soils which cannot be confused the one for the other.

The four main types of soil to be dealt with and which certainly occupy by far the greater part of the Indian cultivated area, are the Indo-Gangetic alluvium, the black cotton soil or *regur*, the red soils lying on the metamorphic rocks of Madras and the laterite soils which are met with in many parts of India.

There are doubtless other minor classes of soils, but they neither possess such characteristic differences in appearance nor are they distributed over such extensive areas as the four types referred to. For instance stretches of alluvium are situated at the mouths of the rivers Mahanadi, Godaveri, and others, but the area of these deltas bears no comparison to the Indo-Gangetic alluvium; and again I found the soil covering the Dharwar system in the Dharwar District quite different from the *red* soils of the metamorphic rocks in Madras Presidency.

Probably a more exhaustive study of these various smaller classes of soil might be worth while undertaking. My first aim was, however, to be able to form an idea of the general constitution of the four classes named, to determine in what essential respects they differ from one another, and whether any of them may be said to be usually rich in plant food.

4. In addition to an examination of these main types of soils, analyses of several other descriptions of soil have been undertaken. Thus ten soils of brown coloured alluvium, principally from the valley of the Cauvery, have been analysed; and six soils from a coffee estate in the Shevaroys have also been examined. These are dealt with in the first part of this chapter.

I have also submitted reports on the composition of soils which constituted enquiries of a more special nature, and these find a place in the second part.

Thirdly, a resumé of my investigations into *usar* forms a third section.

A brief notice of my enquiries into the reclamation of ravine lands then follows.

Lastly, I add a brief paragraph on the subject of the exhaustion of Indian soils.

The Soils of the Indo-Gangetic Alluvium.

5. It is unnecessary to define to what area the Indo-Gangetic Alluvium belongs, or to say that from Karachi on the west to Assam on the east, one may pass without finding a single pebble; the only rocky particles larger than sand, which this great expanse of land contains, is the nodular limestone which has been called *kankar*, and which has been formed by the deposition of calcium carbonate in the soil within a few feet of the surface. This large expanse of land consists then generally of a yellow coloured alluvium, sometimes sandy, sometimes becoming a stiff clay, and the latter is also more of a blue grey in places. Occasionally too sand *duns* or hills have been formed by the wind. A number of soils which are fairly representative of this alluvial area have been analysed, and these analyses are exhibited in the accompanying statement No. 1.

Statement No. 1.

Analyses of Soils of the Indo-Gangetic Alluvium.

Description.	Sandy Soil.	Sandy.	Loams.	Loamy Soils.					Clay Soils.			Calcareous Soil.
Locality.	Ison sand belt.	Ison Ganges Doab.	Burdwan Farm.	Cawnpore District.	Changa Manga plantation surface.	Changa Manga plantation sub-soil.	Dumraon Farm surface.	Bahr, Patna District.	Dumraon Farm sub-soil.	Bahr, Patna District.	Sibpur, Calcutta.	Partabgarh, Oudh.
No.	20—93.	22—93.	339—94.	15—93.	386—95.	387—95.	33—95.	302—96.	41—95.	299—96.	17—96.	127—93.
Insoluble silicates and sand	91·72	88·08	84·31	84·84	77·03	86·06	86·82	82·96	80·90	72·64	73·58	57·52
Iron (Fe_2O_3)	2·36	3·10	5·58	4·52	5·74	4·48	4·09	4·59	6·12	7·58	6·36	3·23
Alumina (Al_2O_3)	2·92	4·38	6·09	5·30	4·36	4·36	4·57	5·11	6·50	9·89	7·93	3·39
Manganese (Mn O)	...	...	·12	...	·11	·11	·10	·11	·14	·14	·11	...
Lime (C_a O)	·35	·47	·28	·91	·93	1·03	·30	1·78	2·07	1·01	1·52	14·54
Magnesia (M_g O)	·78	·32	·66	·52	1·97	1·48	·76	1·53	1·17	1·64	1·61	1·86
Potash (K_2O)	·33	·64	·56	·16	·57	·76	·48	·66	·73	·82	·64	·44
Soda (Na_2O)	·08	·09		·03	·25			·30				·02
Phosphoric acid (P_2O_5)	·08	·08	·04	·10	·19	·09	·08	·13	·08	·07	·11	·18
Sulphuric acid (SO_3)	·04	·05	·02	*Nil*	*Nil*	·03	*Nil*	*Nil*	*Nil*	*Nil*	·03	·08
Carbonic acid (CO_2)	·27	·37	·21	·71	·43	·47	·01	1·10	·05	·28	1·35	11·42
Organic matter and combined water	1·07	2·42	2·13	2·91	8·42	1·13	2·79	1·73	2·24	5·93	6·76	7·32
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen	·027	·081	·042	·046	·237	·043	·049	·045	·041	·051	·065	·180

B 2

Sandy soil.—Among these soils only one (No. 20—93) is a really sandy soil. It was taken from a well-cultivated field of what has been called the "Ison Sand Belt" in the Cawnpore District.

Sandy Loams.—Two samples are of sandy loams. The one, No. 22—93, is from a very fertile tract lying between the Ison and Ganges, also in the Cawnpore District. The other, No. 339—94, is a sample of the soil of the Burdwan Experimental Farm, and may likewise be considered a typical sandy loam.

Loams.—The majority of the samples analysed are loams. The first, No. 15—93, is from the Cawnpore District; Nos. 386 and 387—95 are from the Changa Manga Fuel Plantation in the Punjab; No. 33—95 is the surface soil of the new Farm at Dumraon; No. 302—96 is the mean of the analyses of two loams from the Bahr Sub-division of the Patna District.

Clays.—The three following samples were more or less clayey soils, though none of them could be considered a stiff clay.

No. 41—95 is the subsoil of the Dumraon (new) Farm. No. 299—96 is a clayey soil from the Bahr Sub-divison of the Patna District.

No. 17—96 is a sample of the soil (surface) from the Sibpore Farm.

Calcareous Soil.—Lastly, No. 127—93 is a calcareous soil from Captain Chapman's estate in the Partabgarh District of Oudh. Calcareous soils occur very rarely.

6. Beds of *kankar* commonly underlie both the alluvium and the *regur*; perhaps similarly other soils. In the case of the alluvium this *kankar* is only found mixed with the surface soil when the bed of *kankar* is very near the surface. Otherwise the surface soil of the alluvium is remarkably free from this material. In the black cotton soil (*regur*) also, *kankar* frequently lies in beds a few feet under the surface, but *in addition* small pieces of the same material are found intermixed throughout the soil, and in some of these soils the amount of calcium carbonate approaches 10 per cent. Excepting in the case of the soil from Captain Chapman's estate, the largest amount of carbonic acid in any of the alluvial soils examined was 1·35 per cent. Assuming this to be entirely combined with lime, it corresponds to 3·06 per cent. of calcium carbonate.

The land on Captain Chapman's estate from which the calcareous sample was taken, is a low-lying area which until recently was annually inundated by the river Ganges, and the large amount of lime is doubtless due to the agency of shell-fish.

7. Of these alluvial soils generally it may be noted that the amount of phosphoric acid, though not large, is frequently more than other classes of Indian soils usually contain. The amount of potash, in those samples in which it has been determined, is sufficient. The amount of nitrogen and organic matter varies within much about the same limits as in those examples quoted by Dr. Voelcker (paragraph 58). They are low, excepting in two cases, the one being the surface soil of the Changa Manga Fuel Reserve, the other the calcareous soil from the reclaimed land at Captain Chapman's estate. Both these have been placed under conditions which are particularly favourable to an accumulation of organic matter and nitrogen.

In other respects these soils are similar in composition to European loams and clays. The amount of iron and alumina is perhaps somewhat higher, but the divergence is not great. The sandy soil No. 20 contains 2½ per cent. of each, and in the others the proportion rises, until in the clays it amounts to 6 or 8 per cent. of each. The proportion of magnesia, which varies from ½ per cent. in the more sandy soils to 1½ per cent. in the clays, is perhaps somewhat higher than in English soils generally.

It is to be noted that whilst sulphates are generally absent from the *regur*, the red soils of Madras, and the laterite soils, these alluvial soils frequently contain a small amount.

Brown Alluvial Soils from Madras.

8. A number of samples of brown or greyish brown alluvial soils have been received from the Madras Presidency, principally from the valley of the Cauvery, and whilst they differ a good deal in colour and texture, still they

may be conveniently placed in one class and described together. They are essentially different from the *regur*, the red soils, and laterites, as also from the alluvium of the Indo-Gangetic plain. They appear to be free from pebbles, and although the proportion of iron and alumina is high in the loamy ones, not one of them could be considered clayey.

The statement No. 2 exhibits their composition, and the following are the descriptions which were sent with them.

No. 374—96, Bellary District, Hospet Taluk.—"Brown alluvium of great depth from the bed of a ruined tank. Cholum grows nearly 20 feet high on this soil, and the stalks are chiefly used for fuel. The grain produced is more bitter than that produced elsewhere; *hariali* grass (*Cynodon dactylon*) grown on this soil is also bitter and fetches a low price in the market."

No. 375—96, Coimbatore District, Erode Taluk.—"Black loam, lies on a gravelly substratum at a depth of 2 or 3 feet; is therefore unfit for cocoanuts. The ryots complain that the soil of this and the neighbouring fields is not retentive enough and needs to be more frequently watered than the fields further down the Cauvery valley; irrigated under the Kalingarayan channel from the Bhavani."

No. 377—96, Trichinopoly District, Kulitalai Taluk.—"Clay, black; more mellow and clayey than No. 375. At a depth of 3 to 5 feet there is a bed of impalpable black sand; cocoanuts and plantains thrive on this remarkably and nowhere in the Cauvery valley are cocoanuts more extensively cultivated. The nuts are comparatively small." (The sample received could not be called either black or clayey; it consisted of a dark brown loamy soil.)

No. 331—96, Trichinopoly District, Perambalur Taluk.—"Red loam; this is the kind called *Yerramasaka* in the ceded districts; locally called *Sempidippu karambai.*" The sample received consisted of a peculiarly soft dark *brown* soil, inclined to adhere in soft lumps. It will be noted that No. 75—96 (*vide* para. 20) is also called *Yerramasaka*, but the two are absolutely different in appearance and nature.

No. 381—96, South Arcot District, Chidambaram Taluk.—"Loam, pale on the surface but black below. Though entered in the Settlement Register as black clay, it is fairly friable; called in Tamil *palpottai*; produces good crops of ground nuts, overlies a calcareous stratum at a depth of more than 5 feet."

No. 384—96, South Arcot District, Cuddalore Taluk.—"Loam; retains its natural red colour; as thin as No. 383; taken up for cultivation only a few years ago; less fertile than No. 383."

No. 382—96, South Arcot District, Cuddalore Taluk.—"Sandy soil with fine particles; black; uniformly friable to a great depth; has been cropped with *kambu* (Pennisetum typhoidium); every year mixed with ground nuts in alternate years; *gingelly* following *kambu* in other years; fertile."

No. 383—96, South Arcot District, Cuddalore Taluk.—"Loam; natural colour red; but now turned grey, having been manured liberally with ashes and canal silt; overlies a bed of sand stone at a depth of 12 to 18 inches; has been cropped with ground nuts almost every year for more than 20 years."

No. 385—96, South Arcot District, Cuddalore Taluk.—"Sandy; red soil from the right bank of the Gaddilam river near Pauruti; has now turned grey having been plentifully manured with ashes and tank silt; cropped incessantly with ground nuts and *kambu* for many years; is more than 20 feet deep and is red throughout except near the surface."

No. 386—96, South Arcot District, Villupuram.—"Loam; light coloured; has turned grey having been manured plentifully with ashes and tank silt; the soil consists of fine particles and is uniformly friable to a great depth. Has been cultivated with ground nuts with occasional change of crops for more than 30 years."

Nos. 383 and 386, although described as loams, should be classed as sandy soils.

9. Of these ten soils, all the loamy ones contained high, some of them very high, proportions of iron and alumina. The amount of lime is small

excepting in one case, and in no case is there much carbonate of lime. The amount of magnesia is high in five of the samples.

Of potash, only one (No. 382) contained a low proportion. Of phosphoric acid the amount is in no case large, and is in much the same proportion as occurs in the other descriptions of soil from Madras. The amount of nitrogen is as small as in most other classes of Indian soils. The amount of volatile matter is high in some cases, but this occurs in those soils which contain high proportions of iron and alumina, and is doubtless due to loss of combined water.

Judging by the descriptions they are very fertile soils, but it would also appear that they are regularly manured.

Statement No. 2.

Analyses of Brown Alluvial Soils from Madras Presidency.

District.	Loams.						Sandy soils.			
	Bellary.	Coimbatore.	Trichinopoly.		South Arcot.		South Arcot.			
Taluk.	Hospet.	Erode.	Kulitalai.	Perambalore.	Chidambaram.	Cuddalore.	Cuddalore.	Cuddalore.	Cuddalore.	Villupuram.
No.	374—96.	375—96.	377—96.	331—96.	381—96.	384—96.	382—96.	383—96.	385—96.	386—96.
Insoluble silicates and sand	57·62	78·46	75·79	66·03	82·33	77·09	95·04	87·61	96·01	93·71
Iron (Fe_2O_3)	17·30	4·84	7·12	10·33	4·84	8·27	2·05	3·46	1·65	2·68
Alumina (Al_2O_3)	10·23	7·97	7·86	15·28	5·85	10·60	1·06	3·89	·90	1·12
Manganese (Mn O)	·26	·07	·07	·20	·09	·05	·04	·06	·03	·04
Lime (Ca O)	·58	·38	·44	1·23	·32	·05	·15	·10	·09	·18
Magnesia (Mg O)	1·82	1·23	1·54	1·87	1·04	·21	·51	·26	·20	·33
Potash (K_2O)	·27	·43	·19	·28	·98	·10	·03	·11	·07	·09
Soda (Na_2O)	·38	2·42		·07		·06		·16		
Phosphoric acid (P_2O_5)	·10	·09	·14	·08	·06	·14	·03	·10	·04	·04
Sulphuric acid (SO_3)	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*
Carbonic acid (CO_2)	·16	·03	·03	·08	·06	·09	·13	·09	·14	·09
Organic matter and combined water	11·28	4·08	6·82	4·55	4·43	3·34	·96	4·16	·87	1·72
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen	·091	·105	·057	·046	·017	·008	·010	·009	·023	·019

Regur, or "Black Cotten" Soils.

10. With two exceptions the soils referred to in the accompanying statement No. 3 are all true *regur of good quality*; the soil from Coimbatore No. 292—94 and No. 114—95 from Anantapore are a bit gravelly. The following are the descriptions which accompanied the samples.

No. 380—96, Madura District, Tirumangalum Taluk.—"Black loam; one of the four classes of black cotton soil recognised in Madura and Tinnevelly. It is called *Veppal*. The characteristics are a pale white colour of the surface and such an open texture that it is not fairly retentive. Is several feet deep and rests on *kankar*."

(This is a sample of good *regur* and contained small bits of white *kankar*. It is not clear how the land can have a white colour.)

No. 329—96, Madura District, Tirumangalum Taluk.—"Black clay; though there had been no rain for a long time, there was moisture 9" below the surface."

No. 330—96, Madura District, Tirumangalum Taluk.—"Black clay; this is the same as what is called *choudu regada* in the Ceded districts, but not quite so hard."

No. 332—96, Trichinopoly District, Perumbalur Taluk.—"The soil is a black loam not injured by heavy rainfall." (Although this soil is described as a *loam*, it has all the characteristic appearances of a good *regur*, and the analysis shows that its composition coincides with the other *regurs*. The proportion of iron and alumina, though somewhat high, is not exceptional, and the amount of lime normal, as is likewise the nitrogen and organic matter; the proportion of phosphoric acid is very small. I have therefore placed it among the good *regur* soils.

Statement No. 3.

Analyses of Black "Cotton" Soils (Regur).

District.	Madura.			Trichinopoly.	Coimbatore.	Anantapore.		Kistna.					Kurnool.			Cuddapah.	Nagpur Farm.	
Taluk.	Tiramangalum.			Perambalur.	Coimbatore.	...	Gooty.	Guntur.	Guntur.	Sattenapalle.	Narsaraopet.	Narsaraopet.	Cumbam.	Ramallakot.	Pattikonda.	Pulivendla.	Surface soil.	Subsoil.
No.	386—96	329—96	330—96	332—96	292—94	114—95	248—96	72—96	73—96	76—96	77—96	78—96	80—96	247—96	249—96	252—96	276—96	277—96
Insoluble silicates and sand.	72·68	68·97	72·89	65·16	69·31	78·50	62·15	72·32	71·66	70·68	64·92	68·29	71·94	63·74	64·91	56·68	63·71	67·01
Iron (Fe_2O_3)	6·09	6·96	6·27	9·27	5·31	4·34	6·25	6·67	6·64	7·04	6·60	6·96	5·60	6·54	6·33	8·74	11·25	11·50
Alumina (Al_2O_3)	8·39	10·84	10·84	13·76	8·51	6·33	12·06	8·50	8·74	10·61	10·91	10·20	8·62	11·83	9·99	12·77	9·39	10·41
Manganese (Mn O)	·19	·22	·20	·25	·20	·21	·15	·14	·12	·18	·10	·09	·12	·16	·16	·22	·26	·25
Lime (Ca O)	2·42	1·96	2·20	2·18	4·62	2·00	5·35	1·44	1·16	1·67	3·53	3·43	3·31	3·66	4·90	4·95	1·32	1·76
Magnesia (Mg O)	1·86	1·90	2·01	2·47	2·44	1·95	2·50	2·06	2·39	2·02	2·55	2·67	1·94	2·78	2·35	3·09	1·79	2·19
Potash (K_2O)	·16	·26	·23	·14	·47	·43	·21	·68	·48	·68	·79	1·14	·64	·43	·28	·67	·45	·51
Soda (Na_2O)			·37	·01	1·00	·26		·31		·21	·57	1·30		·21	·05			
Phosphoric acid (P_2O_5)	·07	·03	·02	Trace	·19	·03	·06	·07	·06	·05	·07	·08	·08	·05	·07	·08	·06	·05
Sulphuric acid (SO_3)	*Nil*	*Nil*	·61	*Nil*	·06	*Nil*	·03	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	·01	*Nil*	*Nil*	*Nil*
Carbonic acid (CO_2)	2·00	·25	1·09	·91	2·77	1·71	3·58	·16	·16	·49	1·96	1·88	2·40	2·32	3·15	3·43	·44	·53
Organic matter and combined water.	6·14	8·61	3·87	5·85	5·12	4·24	7·66	7·65	8·59	6·37	8·00	3·96	5·35	8·28	7·80	9·37	5·83	5·79
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen	·019	·030	·025	·024	·027	·016	·043	·049	·036	·020	·030	·012	·045	·034	·035	·028	·050	·047

No. 292—94, Coimbatore District, Coimbatore.—This soil is a true *regur*, but somewhat less coherent than most.

No. 114—95, Anantapore District.—This is described as "rather inferior black soil." It is also somewhat gravelly and less coherent than most.

No. 248—96, Anantapore District, Gooty Taluk—"*Regur* clay; *nalla regadi* or pure black cotton soil."

No. 72—96, Kistna District, Guntur Taluk.—"*Regur* clay (*banka regada*); known locally as *kullu regada* literally rotting *regada*. It is so retentive of moisture that crops thrive on it only in years of moderate or deficient rainfall. Contains small pieces of limestone called in Telugu *guvarayi*. The larger the proportion of the limestone, the worse the soil is held to be."

No. 73—96, Kistna District, Guntur Taluk.—"*Regur* clay (*banka regada*); called locally *pulludu regada*; literally *sour regada*. Requires more rain for the successful cultivation of crops than *kullu regada*. Contains a larger proportion of *guvarayi*." (As a matter of fact the sample received did *not* contain a larger amount of *guvarayi* limestone, but just about as much as No. 72 to which this comparative remark has reference.)

No. 76—96, Kistna District, Sattenapalle Taluk.—"*Regur* clay; the soil is remarkably hard; does not crack in summer so much as the ordinary black cotton soil. Does not easily get softened by immersion in water. Agricultural implements are worn out comparatively soon. Indigo leaf produced from this sort of soil, gives, as a rule, a larger proportion of dye than that produced elsewhere; requires plenty of rain for the successful cultivation of crops."

(So far as the eye could tell this soil was a good *regur* of normal quality and contained but little *kankar* limestone; the analysis is also quite normal.)

No. 77—96, Kistna District, Narsaraopet Taluk.—"*Regur* clay; *krishna regada*."

No. 78—96, Kistna District, Narsaraopet Taluk.—"*Regur* clay; *pulludu regada*. There is scarcely any *guvarayi*."

No. 80—96, Kurnool District, Cumbam Taluk.—"*Regur* clay; locally called *nalla or krishna regada*."

No. 247—96, Kurnool District, Ramallakot Taluk.—"*Regur* clay; cracks much in the dry weather; known as *accha regadi* or pure black cotton soil."

No. 249—96, Kurnool District, Partikonda Taluk.—"*Regur* clay; a clay soil called locally *marabhumi*, very hard but retentive of moisture; fertile."

No. 252—96, Cuddapah District, Pulivendla Taluk.—"*Regur* clay; called locally *banka regadi* (that is black clay soil); the cracks were wide and deep."

Nos. 276—96 and 277—96, Nagpur.—"This is the soil of a plot at the Experimental Farm which has not been manured for a long period of years. A crop of wheat (averaging some 600lb of grain per acre) has been taken off it for 12 years.

11. It will have been observed that in several instances the same vernacular name is applied to two or more of the samples.

For example Nos. 73 and 78—96 from the Kistna District are both called *pulludu regada*; No. 73 is said to contain "a larger proportion of *guvarayi* (*kankar*) than *kullu regada*," whilst No. 78 is said to contain "scarcely any *guvarayi*." In appearance the samples were not notably different from one another. The analysis shows that No. 73 contains scarcely any calcium carbonate; No. 78 contains a fairly high proportion. No. 72—96 is described as *banka regada*, known locally as *kulu regada*; No. 73 is called *banka regada*, known locally as *pulludu regada*. The former is said to be "so retentive of moisture that crops thrive on it only in years of moderate or deficient rainfall," whilst No. 73 is said to require "more rain for the successful cultivation of crops than *kullu regada*." One might have expected some difference in the composition of these two soils, such as less iron and alumina or more *kankar* in No. 73, but such is not the case; the composition of the two is as nearly alike as possible.

No. 252—96 is also called *banka regadi*, but this soil has a composition widely divergent from Nos. 72 and 73.

No. 77—96 is described as *krishna regada*; No. 80—96 as *nalla* or *krishna regada* and No. 248—96 as *nalla regadi*.

In composition No. 248 is similar (except in the amount of alkalis) to No. 77, but No. 80 differs considerably from these in several respects.

Thus it would seem that these terms are not related at all to the chemical composition of the soils. Doubtless to the people they have a comparative significance, but if this be so, it is probable that they are related to certain *physical* peculiarities, dependent as much on the nature of the subsoil or drainage as upon anything else.

12. If the analyses of these 18 *regur* soils be examined, it will be seen that there is, comparatively, but little variation in their composition. The individual constituents may with advantage be examined.

Insoluble Silicates and Sand.—One sample contained only 56 per cent. and two others with appreciably less than 65 per cent.; there is only one which contained more than 75 per cent.; 15 samples contained proportions varying between 65 and 75 per cent.

Oxide of Iron.—The majority of the samples contained from about 5½ to 8½ per cent. One sample contained only 4·3; the Nagpur samples contained over 11 per cent and the one from Trichinopoly District 9·2, but these appear to be extreme limits.

Alumina.—The greater number of the samples contained from 8·5 to 11 per cent. of alumina. Two samples had only 6·3 and 6·8 respectively, whilst in four others there was 11·8, 12·0, 12·7, and 13·7 per cent.; the extreme variation being about the same as in the case of iron. In all the Madras samples there was more alumina than iron by about 1 or 2 per cent. In the Nagpur samples the reverse is the case.

Manganese.—The amount of this constituent is very constant; the lowest amount found being ·09, the highest ·26. In two cases the amount is less than ·12 and in one case it was ·26, but all the other samples contained amounts varying from ·12 to ·25 per cent. of manganese. In the statement of analysis the manganese is entered as Manganous oxide. It may be that some part of the manganese exists as dioxide, which I have at least once found in an Indian soil, but the amount of dioxide is certainly not great, and in the presence of organic matters such small quantities are difficult or impossible to detect.

Lime.—The proportion of lime varies in the samples considerably, not only in its total amount but also in the condition in which it exists.

With one exception, it exists in part as carbonate and in part as silicate. In those samples in which there is 2 per cent. or more lime, the greater part is carbonate; where, however, the total amount of lime is less than about 2 per cent., the greater part exists as silicate. These soils generally contained from 2 up to 4 or 5 per cent.

Magnesia.—The amount of magnesia is high in all samples, and varies from 1·3 to as much as 3·1 per cent. In two samples there is appreciably less than 2 per cent. and three in which it is more than 2½ per cent., namely, 2·6, 2·7, and 3·0; in the remainder of the samples the variation falls between the limits of 2 to 2½ per cent.

Alkalis.—The alkalis vary very considerably, the lowest proportion being ·15 per cent., the highest 2·44 per cent. The amount is, however, in the majority of samples, unusually large. The potash, in those samples in which it has been determined separately, is in all cases high.

Phosphoric Acid.—The amount of this valuable plant food is small in nearly all cases. One sample contained ·19 and another ·23 per cent., but in all the remainder the proportion fell below ·1 per cent. and in many cases much below this figure. These black soils are undoubtedly badly off in this respect.

Carbonic Acid.—The carbonic acid exists in combination with the lime and varies to a greater extent even than does that constituent. Apparently

the carbonate of lime agglomerates together not only as beds of *kankar*, but also as quite small lumps of this material. At any rate many of these soils contain small round bits of *kankar* about the size of mustard seed.

Sulphuric Acid.—Most of the samples contained no sulphates and in no case was the amount anything appreciable.

Nitrogen.—The amount of nitrogen is very small, as is common to Indian soils generally. The smallest amount is ·012 per cent., the highest ·050.

13. *Organic Matter and Combined Water.*—The loss in weight which soils experience when heated moderately is occasioned by the combustion of the organic substances, the expulsion of water chemically united with minerals of the soil, and possibly a little carbonic acid from the calcium carbonate; this latter, however, does not form any material part of the loss. It would, of course, be interesting to know the amount of organic carbon present apart from the "combined water," but this had to be left undone.

A conclusion may nevertheless be drawn concerning its amount. The proportion of "organic matter and combined water" is higher than in most Indian soils. Among the soils representing the Indo-Gangetic alluvium, one from Changa Manga contained 8·42 and the calcareous soil from Partabgarh 7·32 per cent., but in these the loss was principally due to *organic matter*. Two of the clays suffered about 6 per cent. of loss on heating which was probably mainly due to combined water. Among the laterite soils Nos. 284, 285 and 358 suffered considerable loss on heating, principally owing to the presence of large amounts of "limonite" which gives up its one molecule of water when heated. Among the *red soils* from Madras one sample suffered a loss of 7·4 per cent., due principally to combined water. Generally, however, these types of soils suffered very considerably less loss on heating than did the *regur* soils.

On the other hand, when these latter are heated the loss is almost uniformly high, but there are no indications of any particularly large amount of organic matter. They simply change colour from black to a dark brown. If a soil contain any notable quantity of humus its combustion can be unmistakably observed. The proportion of nitrogen is as low in most of those *regur* soils as in other soils which lose only $\frac{1}{2}$ or $\frac{1}{3}$ as much when heated. Thus the nitrogen indicates a low proportion of organic matter. Thirdly, the manner in which these *regur* soils contract on drying indicates a high proportion of hydrated ferric oxide or alumina and either of these compounds would lose the water of "hydration" on being heated. The amount of combined water then must be necessarily much higher in these soils than in ordinary ones.

A further point may be referred to, namely, that soils, whether in India or elsewhere, which contain a high proportion of organic matter, possess a peculiarly dark brown appearance, approaching black, but nevertheless quite different from the colour of *regur*. Thus it appears certain that the greater part of the loss which these *regur* soils experience when heated is due to expulsion of combined water and that there is as little organic matter in them as in most other descriptions of Indian soils.

14. Reference may also be suitably made in this place to the question of the fertility of *regur*. At page 412 of the Geology of India, it is stated that "The fertility of this soil is so great that some of the black soil plains are said to have produced crops for 2,000 years without manure, without having been left fallow, and without irrigation." As to the period named, I do not suppose that Mr. Oldham, when reproducing this statement, assumed there was sufficient evidence to prove that the history of any field is so accurately known that its agricultural treatment can be traced for even as many hundreds of years. But still there is a general belief that these soils are immensely fertile. As to the origin of such a belief, it seems to me that it is due possibly to the fact that the *regur* is usually a more fertile soil than those other soils which frequently adjoin it, such as the red soils, which are certainly in many cases light gravelly soils, with rock not far from the surface. The power which *regur* has of retaining moisture is so great that on this account alone it possesses an advantage over these gravelly red and brown soils situated within the same region as the *regur*.

Then, again, one of the results of the strongly contracting power of *regur* is not only that it forms deep and wide fissures in the land, but also the surface literally crumbles to a coarse powder, and a part of this is annually carried by the agricultural implements, the *bakhar* for example, into the fissures, and consequently there is constantly going on *an invertion* of the soil and what has been subsoil comes to the surface.

These two properties must materially assist in helping the soil to produce crops. But so far from it being the case that *regur* is inordinately rich, it has been pointed out that in the matter of phosphoric acid and nitrogen it is very poor indeed, and if other Indian soils are as poor or even poorer in these particulars than *regur*, one cannot for a moment call it a soil of inexhaustible fertility. The outturn of crops too at the Nagpur Farm on unmanured land is lower than on similar unmanured land of the Gangetic alluvium.

15. In the Geology of India (2nd Edition), page 411, several analyses of black soils are given. The one made by Dr. Macleod (if even approximately correct) is of a soil very different not only to the samples which I have examined, but also to those the analyses of which are published in the same place.

The seven other analyses by Mr. Tween are in some respects in fairly close agreement with mine. The undried soil was employed, and if the mechanically contained water (7 to 10 per cent.) be withdrawn from the analyses and the remaining items calculated for 100 per cent., the figures would become comparable with mine. The silica varies between the same limits as it did in my samples. The iron and alumina *taken together* are also present in similar amount, but whilst, in most of the samples which I analysed, there was rather more alumina than iron, in Mr. Tween's analyses there is more iron than alumina in the soils from Seoni and Indore, the other two containing reverse proportions. The proportion of calcium carbonate too is similar. Mr. Tween left magnesia, alkalis and phosphoric acid undetermined. The amount entered as "organic matter" must have been determined by heating the soil, since there is no other method available, and thus the combined water is included; this item also agrees with what I found.

16. I have thought it desirable to go into these analyses somewhat in detail, because on their evidence it has been assumed that "there appears always to be a considerable quantily of organic matter combined. The black colour appears to be due either to the carbonaceous elements of the soil or to organic salts of iron" (*l. c.*). As to there being any inordinate amount of *organic* matter in black soil, I have already shown that there is no evidence in *support* of such a conclusion, but rather much which is antagonistic to it.

The second of the above assumptions, namely, that the colour is due to the presence of "organic salts of iron," is one difficult to discuss. It was once suggested to me that the black colour of *regur* was due to the presence of some plant which produced a dye from the root. Such a plant has never, so far as I am aware, been found anywhere. Supposing, however, that such had happened, it is true that a quantity, so small as not to materially increase the proportion of "organic matter," might have produced the result. But not only is this a mere assumption; there is in addition much evidence of a conflicting nature.

It is well to bear in mind that these *regur* soils have two peculiarities, the one being the colour, slaty-black to very dark brown black, the other the unusual degree to which they contract on drying. The colour of the land frequently varies more or less, sometimes it appears quite *grey*, but this is obviously produced by the presence of *kankar*; sometimes it appears brown on the sides of cuttings. But I am convinced that there *is* some constant ingredient of these soils which *is* either black or slaty-black. It *may* be that the black coloured ingredient and the ingredient which causes the strong contraction on dying are identical; it is much more probable that they are *not*.

Now referring to the possible presence of "organic salts of iron," it must be remembered that at the high temperature (often 50°-60°C. or 120°-140 F.) to which the surface soil is subjected in India during long months each year, oxidation *must* be rapid and doubtless is so, and one cannot imagine any organic salt of iron remaining unoxidised for generations under such circumstances. Again, supposing some particular plant were constantly producing a dark coloured material, how comes it to do so only in the soil which contracts so peculiarly? Our knowledge of plants is that they do not exclusively grow on some

particular soil. Thus it is difficult to conceive that the colour is due to organic matter at all.

17. At page 414 of the Geology of India reference is made to Mr. Blanford's paper (Memoirs 4) in which he states that he found *regur* being formed in lagoons by the sea. In a foot-note at page 135 of Memoirs 4(2) Dr. King states that the *regur* described by Blanford was not true *regur*.

Again, in the same paragraph of the Geology of India, reference is made to Mr. Blanford's paper (Records 8) in which he points out the similarity between the mud at the mouth of the Tapti and the *regur* of the neighbouring country, and for geological reasons assumes that the former is now being formed, and that the latter was originally formed, *by the sea*. I have also seen the same country, and I must say that it appeared to me that the black mud at Surat was simply the silt brought down by the Tapti from the neighbouring *true regur*. The flow of the river is stopped at Surat by the tide and the mud has an opportunity to deposit itself.

Messrs. King and Foote concluded that *regur* was formed in marshes, that the now high lying *regur* was originally submerged. Here again this seems to be a conclusion not warranted by facts. It is true that the mud of marshes in Europe, or *jhils* in India, is usually dark coloured ; a colour due in many cases to organic matter and sometimes to ferrous oxide, or again to the clay being itself grey coloured, but unless due to ferrous oxide, the organic matter of marshy land produces a soil of a much lighter brown colour than any true *regur* ; the presence of free ferrous oxide is quite out of the question ; and lastly, the clayey deposit usually formed in *jhils* never has the same black colour nor the extremely high power of contraction which *regur* possesses.

In my opinion one must come to conclusion that the colour of *regur* is not due to organic matter. It is much more probable that *regur* has been formed from some particular rock which, on decomposition, forms not only a highly argilaceous soil, but also, during disintegration, liberates a black or very dark coloured mineral.

Many Geologists have contended that *regur* is the product of the decomposition of trap rocks. Oldham (page 413, Geology of India) says this view cannot be maintained because (1) " basalt generally decomposes into a reddish soil quite different from *regur* in character "; (2) he points out that Hislop's view, that the colour of *regur* is due to impregnation of organic matter, is the most probable theory.

One must of course admit that basalt is decomposing, at least in places, into a red soil, and what is still more puzzling is the fact that, whilst one finds this the case on the steep slopes of the hill-sides, it is just as common to find that *immediately* at the foot of these same slopes comes the true *regur*.

Another point may advisedly be borne in mind, namely, it appears to be admitted that *some* of the *laterite* has been formed from trap. It is clear that *some* trap is decomposing into a red soil entirely different from laterite, and consequently if trap can produce two soils so different as these, why should not some descriptions of trap produce the *regur* ?

18. I have referred to this subject somewhat at length, principally because I believe there is no reason for assuming the colour of *regur* to be due to organic matter, that on the contrary there is every reason for assuming such to be impossible. Not only is the amount of organic matter in *regur* always small, but in no soils from the *plains* of India, *which have been regularly exposed to the sun's influence for a considerable time*, have I found even what is in Europe generally considered an ordinary amount of humus.

One soil from Oudh, which until recently was annually submerged by the Ganges and which has now been reclaimed, contained probably a considerable amount of organic matter ; the surface soil from the Changa Manga Plantation naturally also contained a good deal of humus ; but these are cases of soils having been regularly placed under protective circumstances. Again, the coffee soils from the Sheveroy Hills contained likewise high proportions of the same material, but the temperature in that situation is much below what is common to the plains, and the land is regularly manured and also protected by the shade of the bushes.

19. And if the colour of *regur* is not due to organic matter, it must be due to the presence of some mineral substance.

As a matter of fact *regur* does contain a dark coloured mineral, which I have reason to believe is peculiar to this soil. If *regur* be *boiled* with concentrated sulphuric acid for several hours, the insoluble residue is very dark brown.

I noticed this peculiarity during the process of determining the nitrogen (the first step of which consists in boiling the soil with concentrated sulphuric acid). I have had portions of a number of the Indian soils treated in this manner, specially to note the colour of the silicates insoluble in sulphuric acid, and the following are the notes I made. All were treated in precisely the same way, namely, 10 grammes of the soil was simply boiled with concentrated sulphuric acid for several hours. After cooling, water was added, and the sand washed by decantation. The colour of the latter was then noted.

In the case of Nos. 329, 330, 332, 292, 248, 72, 73, 77, 78, and 249, all good *regur* soils, the silicates were almost entirely very dark brown or black coloured, and white silicates could only be seen clearly by placing the whole in a strong solution of mercuric iodide and potassium iodide (in which the material floated), and then by carefully decreasing the density of the solution with water, the first portions to sink were white, the main part consisting of the black silicates remaining on the surface.

Of the soils from the Indo-Gangetic alluvium, the silicates of the Changa Manga soil were nearly entirely white; those of the Burdwan soil were nearly entirely white, but included some little black silicates; the Bahr clay soil contained a good deal of black silicate; that of Dumraon soil was nearly all white, but included a little black silicate. Among the laterite soils the silicates had the following colour :—No. 282, mostly white, little black; No. 218, mostly white, some red; No. 284, mostly dark red. The red colour of these "silicates" was quite different from the dark brown of the *regur* soils, and could not be for a moment mistaken for it.

The red soils from Madras Presidency yielded silicates of the following colour :—Nos. 327 and 291 mostly white, with a little black; No. 74 mostly white, with some red and black; No. 333 mostly white, with some red (like the silicates of laterite).

Thus, whilst some of the other soils contained insoluble silicates of a colour similar to that of the *regur* soil, the amount in such cases was always small, whilst, as already observed, the insoluble matter of the *regur* soils was almost entirely very dark brown. It need hardly be pointed out that during the process of boiling the soil with sulphuric acid all organic matter is destroyed, and that the colour of the resulting silicates cannot be due to organic matter at all.

STATEMENT No. 4.

Analyses of other Black Soils.

DISTRICT.	KISTNA DISTRICT.	MADURA DISTRICT.	KURNOOL DISTRICT.	KISTNA DISTRICT.
Taluk.	Vinukonda Taluk.	Teramangalum Taluk.	Pattikonda Taluk.	Guntur Taluk.
	79—96	328—96	251—96	75—96
Insoluble silicates and sand . . .	90·70	82·11	59·45	73·83
Iron (Fe_2O_3)	2·53	5·70	9·08	9·09
Alumina (Al_2O_3)	2·18	5·19	11·86	6·60
Manganese (Mn O)	·06	·12	·12	·14
Lime (Ca O)	1·13	1·10	4·41	·88
Magnesia (Mg O)	·65	1·27	3·18	1·53
Potash (K_2O)	·37	·24	·56	·20
Soda (Na_2O)	·06	·86		
Phosphoric acid (P_2O_5) . . .	·32	·06	·05	·17
Sulphuric acid (SO_3) . . .	*Nil*	·15	·06	*Nil*
Carbonic acid (CO_2) . . .	·45	·93	3·04	·14
Organic matter and combined water (difference).	1·55	2·27	8·19	7·42
	100·00	100·00	100·00	100·00
Nitrogen	·006	·008	·036	·047

Other "Black" Soils.

20. Among the samples of soil which I have received from Madras, are three or four which are either described as "black loams" or have a similarity in colour to the *regur*, but which are certainly not *pure regur*. They vary much in composition and appearance. The analyses are set out in statement No. 4.

No. 79—96, Kistna District, Vinukonda Taluk—Is described as "*regur* loam, locally known as *pati mannu*, which is specially preferred for the cultivation of tobacco and chillies. It is from this sort of soil that saltpetre is manufactured."

Regarding this remark, I must say that the sample contained no trace of nitrates, and, as will be evident from the analysis, there was very little nitrogen in it at all. It is a very dark coloured sandy soil, containing about 1 per cent. of calcium carbonate; much less iron and alumina and magnesia than *regur*; the amount lost on heating is also very small, and indeed is a very poor soil in every respect, excepting in that of phosphoric acid, of which the proportion is high.

It is not particularly surprising that no nitrates were present, because I imagine that the remark applies not so much to the particular land from which the specimen was selected, as to the fact that nitrates are found in similar soil *in another situation*. But it *is* somewhat surprising that it should be described as a good soil for the cultivation of chillies and tobacco, since land which is retained for the growth of these crops is usually kept in good "heart" by liberal allowances of manure. The assessment is entered as Re. 1 which is low, and one must assume that *this* particular field is not utilized for the purpose in question, but rather that similar land of other fields are kept for the purpose.

No. 328—96, Madura District, Teramangalum Taluk—Is described as "black loam, called *ilakkali pottal*; it conserves moisture very well. The soil was whitish on the surface. Cotton thrives on it." It is a grey sandy soil containing very little organic matter and nitrogen and phosphoric acid, and one would not have expected it to "conserve moisture well."

No. 251—96, Kurnool District, Pattikonda Taluk—Is described as a "*red* loam; hard and saline and *grey* coloured; requires light and frequent showers; called locally *tella kattu nela*." The term "red" is doubtless a clerical error. It is a grey soil full of fine *kankar* and pieces of rock, but having also something of the appearance of *regur*. Indeed, the analysis indicates this; the silicates are low, the iron and alumina high, the proportion of carbonate of lime high (the carbonic acid is equivalent to 6·90 per cent.), the high magnesia, with alkalis and phosphoric acid, loss on heating and nitrogen all in similar proportion to that in *regur*,—in short a composition which could not by itself be distinguished from that of a good *regur*. It is probable that this is a true *regur* containing enough *kankar* and coarse rock to give it the texture of a loam rather than that of a good "black cotton soil."

No. 75—96, Kistna District, Guntur Taluk—Described as "regur clay; locally known a *yerramasaka*." The soil had a dark brown colour and differed somewhat in appearance from true *regur*, though doubtless there was some *regur* in it. It has nevertheless a general composition similar to *regur* and a very fair proportion of phosphoric acid.

Laterite Soils.

21. In the accompanying statement No. 5 are set out the analyses of a number of soils which have been named as "laterite" by the senders. When summing up the evidence as to the origin of laterite, Mr. Oldham (Geology of India, page 385) writes:—

"From what has gone before it will be seen that the subject of the origin of laterite is still wrapt in obscurity. None of the various hypotheses that have been propounded is completely satisfactory, nor is it possible to come to any final conclusion till an agreement is come to as to the meaning of the word laterite."

If then it is difficult for the geologist to decide what is "laterite," it becomes practically impossible for the agriculturist to say what is a "laterite soil."

Those "laterite soils," that is, soil lying on or adjacent to, what had every appearance of being laterite rock, which I have seen, had all a bright red appearance when dry. But as will be seen when discussing the analyses of the samples which I have analysed, some at least are probably not true laterite.

22. The following are the descriptions of the soils :—

No. 218—96—Is the surface soil of a field at Saidapet, Madras. The soil consisted of a coarse brick-red gravel. It will be observed that there is practically no lime, no phosphoric acid and a very small proportion of nitrogen.

Nos. 280—96 to 283—96.—These four samples, two of surface and two of subsoil, were sent by the Deputy Commissioner of Hazaribagh. When sending them he wrote : "I have the honour to submit two samples of laterite soil, or the nearest approach to it, since laterite soil cannot be found in this district."

Statement No. 5.

Analyses of Laterite Soils.

District.	Chingleput.	Hazaribagh.		Hazaribagh.		Lohardaga.		Singhbhum.	Manbhum.			
Taluk.	Saidapet.	Surface soil.	Subsoil.	Surface soil.	Subsoil.	Surface soil.	Subsoil.	Surface soil.	Surface soil.	Surface soil.	Surface soil.	Surface soil.
	218—96.	230—96.	231—96.	232—96.	233—96.	234—96.	235—96.	358—96.	360—96.	362—96.	364—96.	366—96.
Insoluble silicates and sands	76·86	78·62	74·84	80·46	76·96	29 67	33·66	59·06	90·07	85·50	90·29	90·34
Iron ($Fe_2 O_3$)	10·09	6·35	6·96	6·12	6·40	48·71	42·08	26·64	4·27	5·68	2·90	3·17
Alumina ($Al_2 O_3$)	8·84	8·98	11·57	7·19	11·31	8·81	13·89	7·27	2·59	4·00	4·49	2·95
Manganese (Mn O)	·19	·39	·28	·50	·33	·07	·06	·48	·09	·11	·09	·06
Lime (Ca O)	Trace	1·50	·96	1·72	·94	·38	·45	·28	·14	·47	·14	·38
Magnesia (Mg O)	·77	·66	·81	·38	·51	·21	·20	·33	·31	·60	·28	·36
Potash ($K_2 O$)	·09	·43	·70	·38	·44	·10	·27	·27	·14	·40	·19	·25
Soda ($Na_2 O$)	·17	·21		·32		·04						
Phosphoric acid ($P_2 O_5$)	Trace	Trace	Trace	Trace	·04	·64	·26	·08	·18	·30	·04	·06
Sulphuric acid ($S O_3$)	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*
Carbonic acid ($C O_2$)	·12	·12	·08	·12	0·5	·06	·12	·16	·28	·06	·05	·38
Organic matter and combined water	2·87	2·74	3·80	2·81	3·02	1·31	9·01	5·43	1·98	2·38	1·53	2·05
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen	·015	·039	·032	·030	·026	·010	·010	·024	·016	·032	·031	·036

These samples were bright red coloured. They contain comparatively much manganese, and more lime than any of the other laterite soils examined, though for agricultural soils they are not by any means too well off in this particular. The amount of phosphoric acid is very low, being less than $\frac{1}{100}$ of a per cent. in three of them. The proportion of nitrogen, though higher than in some of the other laterite soils, is nevertheless low from the agricultural point of view.

Nos. 284 and 285—96.—These two, a surface and a subsoil, were received from the Deputy Commissioner of Lohardaga and were selected by the District Engineer, who wrote :—

"The accompaying specimens, I believe, are of the laterite soil of this district or a fair representative of it. As far as I have seen, the soil is not a compact mass, but loose and gravelly, that is, a mixture of pebbles of various sizes and dust; sometimes there are compact blocks mixed with the gravel; a specimen of a block is herewith submitted. As a rule, these pebbles appear to be partially fused and at places there are fragments of quartz and (rarely) other rocks mixed with them. Three specimens are sent herewith. First, surface soil taken within 12 inches in depth (No. 284—96); second subsoil 12 to 24 inches in depth (No. 285—96); third, a compact block found mixed with the loose soil" (not analysed).

The reference to the pebbles appearing partially fused is an indication that this is a true laterite gravel, the "fused" appearance being due to a crust of limonite on them. The analyses indicate that both the surface and subsoil are so rich in iron that they might with more propriety almost be called iron ores. The amount of alumina, though higher than in the alluvial soils of India, is not more than in the other *laterite* soils here referred to.

The proportions of lime and magnesia are low, so also is the nitrogen. The loss on heating is naturally high owing to the high proportion of hydrated peroxide of iron. The phosphoric acid is quite unusually high in comparison with other Indian soils.

No. 358—96—Is a surface soil sent by the Deputy Commissioner of Singbhum and described as laterite. It also contained a very high proportion of iron and is doubtless of lateritic origin. The subsoil, which was pink, had the general appearance of laterite. This soil also contains very little lime and magnesia, and the amount of phosphoric acid is as small as in many other Indian soils.

Nos. 360—96 to 367—96—were eight samples of soil, four surface and four subsoil, sent by the Deputy Commissioner of Manbhum District, Chota Nagpur. Only the surface soils were analysed.

Nos. 360 and 361—Are described as *purulia tand* (high land), the former being the surface 8," the latter the subsoil. It is of a "sandy and gravelly nature." The surface soil, analysis of which is given, consisted of a soft *drab* soil, more like alluvium than anything else; "the subsoil" simply consisted of pieces of quartz with ferruginous veins here and there and had no similarity to the laterite which I have seen at Madras and the Deccan. The composition of the surface soil is merely such as one would expect any alluvium to have, and is devoid of striking peculiarities.

Nos. 362 and 363—Are the surface 9" and subsoil of what is described as *bengabara tand* (high land). "The land is of a sandy and gravelly nature."

The surface soil 9," No. 362, was similar in appearance and colour to No. 360. Its composition is similar to No. 360 in most respects, but the proportion of phosphoric acid is higher, and it contains more nitrogen. The subsoil (not analysed) was a grey lumpy earth with some little pieces of rock intermixed.

Nos. 364 and 365—Are described as "*simalia tand* (high land)." "The land is a sandy and gravelly high land almost free from grass and other weeds." No. 364, the surface soil 9," was a brown soil; the subsoil No. 365 was apparently laterite rock. Nos. 366 and 367 are the surface 12", and the subsoil, of what is described as *Raghunathpur* (high land), "a mixture of mud, sand and gravel." The surface soil was similar to No. 364 in appearance, and the subsoil consisted of laterite rock.

These four surface soils are in most respects similar to one another in composition, and excepting that Nos. 360 and 362 were more of a drab colour, whilst 364 and 366 were of a deeper brown, they were similar in appearance.

There is, moreover, nothing in their appearance or composition which is similar to the other "laterite" soils here referred to, and had it not been for the fact that laterite rock underlies two of them near the surface, I should

have assumed that they had no connection with laterite at all. Under the circumstances all that one can do is to point out the dissimilarity.

23. The other eight samples are probably true representatives of laterite soils, and the somewhat wide variations in their composition, especially in the proportion of iron, illustrates a feature that one might have predicted; for a rock, which itself contains hydrated peroxide of iron (if indeed it does not actually owe its origin to the presence or formation of this substance) might naturally be expected to lose larger or smaller amounts of iron during its decay, the less soluble silicates being left behind. As will be seen, the amount of ferric oxide varies from 4 up to as much as 48 per cent. The amount of manganese appears to be sometimes higher than in soils generally; lime is in no case abundant and generally it is deficient. The proportion of potash, in those samples in which it was determined, is low in only one.

The amount of phosphoric acid varies greatly. In two of the eight samples it is unusually high for Indian soils, but in four it is *very* deficient and in the others the amount is lower than one might wish.

Lastly, there is in no sample any large amount of organic matter or nitrogen, though in some of the samples the latter is present to the same extent as it is in *regur*.

The Red Soils of Madras.

24. Several samples of soil of a distinctly red colour have been sent from Madras and their composition is exhibited in the accompanying statement No. 6.

In the "Geology of India" (2nd Edition), page 410, the red soils of India are thus referred to:—

"The somewhat ferruginous soils, common on the surface of many Indian rocks, and especially of the metamorphic formations, would probably never have attracted much attention but for the contrast they present in appearance to the black soil. They have only been noticed as a rule in papers relating to the black soil country in the western and southern portions of the Peninsula. The commonest form of red soil is a sandy clay, coloured by iron peroxide, and either derived from the rock *in situ* or from the same products of decomposition washed to a lower elevation by rain. The term is, however, frequently used in a very vague, sense apparently to distinguish such soils as are not black, and hence many alluvial soils may be comprehended under the general term. In very many cases, too, it appears to have been applied in Southern India to thick alluvial beds of sand or sandy clays, which are in fact ordinary river or rain wash deposits."

Doubtless these remarks had no reference to *laterite* soils, which are not only frequently red but also of peculiar appearance. But in addition there are also unquestionably soils of such a bright red colour that they could not for a moment be confused with any alluvium. The first six soils in the statement are of this colour.

Statement No. 6.

Analyses of Red Soils from the Madras Presidency.

District.	Coimbatore.	Madura.	Kurnool.	Trichinopoly.			Kistna.
Taluk.	Coimbatore.	Dindigal.	Patikonda.	Perambalore.	Trichinopoly.	Trichinopoly.	Guntur.
No.	291—94.	327—96.	250—96.	333—96.	378—96.	379—96.	74—96.
Insoluble silicates and sand	80·33	90·47	68·10	86·74	88·84	85·99	89·31
Iron (Fe_2O_3)	5·18	3·51	6.32	5·70	4·55	7·09	5·90
Alumina (Al_2O_3)	7·50	2·92	15·84	5·68	3·46	3·19	1·57
Manganese (Mn O)	·10	·08	·07	·10	·06	·08	·08
Lime (Ca O)	1·11	·56	·79	·48	·10	·16	·46
Magnesia (Mg O)	·65	·70	·80	·70	·38	·28	·30
Potash (K_2O)	·36	·24	·23	·05	·28	·11	·45
Soda (Na_2O)		·12	·19	·15			
Phosphoric acid (P_2O_5)	·09	·09	·06	·05	·04	·11	·08
Sulphuric acid (SO_3)	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*
Carbonic acid (CO_2)	·85	·30	·20	·11	·03	·08	·10
Organic matter and combined water	3·83	1·01	7·40	·24	2·26	2·91	1·75
Total	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen	·021	·006	·051	·021	·001	·005	·012

25. No. 291—94, Coimbatore District, Coimbatore—Was a brick red gravelly soil with the rock very near the surface.

No. 327—96, Madura District, Dindigal Taluk—Is described as a "red loam; red sandy soil. The plant called in Tamil *mela-gapundu*, resembling chillies is a common weed on this soil. It is said to be intoxicating to cattle."

No. 250—96, Kurnool District, Pattikonda Taluk—Is described as "red sand, called locally *yerra nela*; needs frequent and copious rainfall for the successful cultivation of crops."

No. 333—96, Trichinopoly District, Perambalur Taluk.—"Red sand; wild indigo grows luxuriantly on the soil. The soil is not far from a hill."

No. 378—96, Trichinopoly District, Trichinopoly Taluk.—"Red sand; overlies a bed of gravel at a depth of 2 to 3 feet; is poor; called in Tamil *pottal*; *cholum* and *samai* (*Panicum miliare*) are the chief crops; natural herbage scanty; becomes somewhat hard and compact in dry weather, unlike most sandy soils, and in that condition emits a peculiar hollow sound when dug with the mamooty. This soil is infected with white ants, every stalk of the stubble of the last *cholum* crop being covered with ant hills."

No. 379—96, Trichinopoly District, Trichinopoly Taluk.—"Red sand, similar to No. 378, but does not become so hard when dry, nor is it so infected with white ants; natural herbage good. Considered fit for ground nuts. *Ragi* does not thrive on this soil."

It will be observed that five of these soils contain higher proportions of iron and alumina than is common to "sandy" soils. The amount of organic matter and nitrogen is very small in five of them; the lime is only very moderate in amount, and the phosphoric acid is distinctly low.

No. 74—96.—Is described as "red loam, locally called *garuva*. Average depth of soil is 2 feet."

Although this soil contains about as much iron as some of the others of this class, the proportion of alumina is very small.

26. Generally regarding these soils it will be seen that the amount of lime is small or only moderate in all, the magnesia is not high and the phosphoric acid is uniformly low. The proportion of potash was fairly high in two of the samples, but decidedly low in a third. On the other hand, the proportion of ferric oxide and alumina is usually high. Indeed their composition is in many respects very similar to the laterite soils already discussed, the chief feature of dissimilarity being in the respective proportions of phosphoric acid. Whilst the laterite soils contained very varying amounts of this valuable plant food, its proportion in these red soils was very uniform, the extreme variation being between ·04 and ·11 per cent.

Coffee Soils.

27. The accompanying statement No. 7 exhibits the composition of some soils from a coffee estate in the Sheveroys, Madras, which Mr. C. G. Lechler very kindly sent from the Brooklyn Estate. It will be observed that one is of newly broken up jungle land, one from land which had borne coffee for two years, two of land which had been under coffee for 12 years, and two which had borne the crop for 40 years.

In physical appearance these soils were all similar, consisting of a nice open soil with a good admixture of organic matter, and, as might be expected, they are in general composition alike. The amount of iron and alumina, especially the latter, is unusually high (they are in no sense *clays*), the amount of lime very low, alkalis only in moderate amount.

In the matter of the important plant foods, organic matter, and nitrogen, phosphoric acid and potash, they are well supplied. Moreover, comparing the soils which had been many years under coffee with the newly broken jungle land, it will be seen that the soil has not suffered any very serious loss by the process. They all contain somewhat less phosphoric acid and a little less nitrogen (in two cases a good deal less) than the newly broken up jungle, but excepting in the case of No. 372, which contained only ·05 per cent. phosphoric acid, the differences are not great; especially when it is

remembered that the samples are not from one small area, but from different parts of the estate, and one cannot of course assume that the land was in each case precisely like No. 371. Doubtless the fertility of the land has been maintained by the careful and constant manuring which the coffee planters provide. These are indeed the only Indian soils, that I have met with, to which the term "rich" can at all be applied.

STATEMENT No. 7.

Analyses of Coffee Soils from Yarcaud, Sheveroy Hills, Madras Presidency.

DESCRIPTION OF SOIL.	Jungle land cleared this year.	Two years under coffee.	Twelve years under coffee.	Twelve years under coffee.	Forty years under coffee.	Forty years under coffee.
No.	371—94.	369—94.	367—94.	368—94.	370—94.	372—94.
Insoluble silicates and sand	56·31	57·88	52·61	56·84	59·72	58·31
Iron (Fe_2O_3)	11·92	9·08	10·10	10·60	9·13	9·77
Alumina (Al_2O_3)	17·31	19·74	19·94	18·62	17·83	18·34
Manganese (Mn O)	·09	·06	·07	·07	·07	·09
Lime (Ca O)	·32	·30	·35	·34	·31	·44
Magnesia (Mg O)	·53	.38	·53	·51	·56	·66
Potash (K_2O)	·20	·14	·15	·21	·31	·29
Soda (Na_2O)	·08	·02	·07	·06		·03
Phosphoric acid (P_2O_5)	·20	·10	·14	·12	·13	·05
Sulphuric acid (SO_3)	*Nil*	*Nil*	*Nil*	·05	*Nil*	*Nil*
Carbonic acid (CO_2)	·10	·02	·10	·09	·03	·03
Organic matter and combined water	12·94	12·28	15·94	12·49	11·86	11·99
Total	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen	·170	·043	·158	·150	·065	·154

28. Having now examined individually the composition of the several different classes of soil, it will be well to summarise the deductions which may be drawn from the information thus supplied, and at the same time compare them with the opinion of Indian soils at which Dr. Voelcker arrived from an examination of such few analyses as were at his disposal when writing his report.

Silicates.—The proportion of silica and silicates was determined by digesting the soil (after gentle ignition) in concentrated hydrochloric acid, and it may be remarked that they were in *all* cases (even the *regur* soils) quite white after this treatment. In the soils of the great alluvial plain, their amount is much about the same as one is accustomed to find in English loams and clays. In the black cotton soil (*regur*) their amount is uniformly low, due principally to the high proportions of ferric oxide and alumina and the water combined with them, and to a lesser degree to the presence of larger amounts of lime and magnesia than many English loams contain. In the red soils of Madras the proportion of silicates is low in two cases, due to the presence of large amounts of iron and alumina; the other samples contain high amounts. The laterite soils yielded very varying amounts of insoluble silicates, which was due almost entirely to the great variations in the amount of iron and alumina, which is a chief characteristic of these soils. In the brown alluvial soils from Madras Presidency, the proportion of silicates is low in the loams, chiefly owing to the high proportions of iron and alumina which these soils contain.

In the coffee soils from the Sheveroys the silicates are very small in amount, due in part to high proportions of iron and alumina, but in part also to high proportions of organic matter.

Iron.—The amount of iron which exists in Indian soils appears to be, in all the classes examined, higher than what one is accustomed to meet with in English soils. In the soil of the Indo-Gangetic alluvium it occurs in proportions varying from 2 up to 7 per cent. In the *regur* its proportion varied from 4 up to 11·5 per cent. In the Madras red soils it varied from 3·5 to 10 per cent.; in those laterite soils, the identity of which could not be doubted, from 6 up to 48 per cent., but in the four doubtful laterites it fell to a much lower figure. In six of the Madras alluviums the proportion was from 5 up to 17 per cent. Lastly, the coffee soils contained from 9 to 12 per cent. Thus there can be little doubt that the amount of iron in Indian soils is large, in some very large indeed.

Alumina.—In the case of the alumina, too, almost all the soils examined contained high proportions. In the soils of the Indo-Gangetic alluvium it varied from 3 up to nearly 10 per cent.; in the *regurs* from 6 up to nearly 14 per cent.; in the red soils there was a good deal of variation, the extreme limits being 1·5 and 15·8 per cent.; in the first eight of the laterite soils it varied from 7½ up to nearly 14 per cent., though the four doubtful laterite soils contained much less; in the Madras alluvium it varied from 6 up to 15 per cent. in the loams, but there was much less in the sandy soils. Lastly, the coffee soils contained the very high proportion of 17 to 20 per cent.

Manganese.—This metal appears to be very widely distributed in the soils of India, though it occurs only in small amount; the proportion in the alluvial soils varied from ·11 to ·30; in the *regurs* from ·1 to ·26; in the red soils from ·07 to ·20; in the laterite soils from ·03 to ·50; in the Madras alluvium from ·03 to ·26 per cent., whilst the coffee soils contained from ·07 to ·09 per cent.

Lime.—The proportion of lime in the soils has been calculated to the oxide for the sake of uniformity. Some of the lime in all the soils exists as carbonate, some part as silicate. As is well known calcareous soils are generally absent from India, the only one of those examined that could fall under this category being the soil of Captain Chapman's estate; the peculiar circumstances under which this soil has been forming have been already alluded to. The soils of the alluvium contained from ·3 to 2 per cent.; the *regur* soils contained more, namely, from 1·0 to 7·7, the greater number of them contained from 2 to 5 per cent; the red soils, the laterites, and the Madras alluvium contained uniformly small proportions, usually less than 1 per cent., and the coffee soils had about 3 per cent.

Dr. Voelcker writes:—

"Speaking generally lime is more plentifully distributed in Indian soils than in English, that is deficiencies of it are not so frequently met with. A notable exception however, which I have found, is in the laterite soil of parts of Southern India, such as the coffee-growing districts of Coorg and Mysore and the tea plantations in the Nilghiris, where I have reason to believe a more abundant supply of lime would be decidedly beneficial."

The evidence now afforded by the analyses quoted substantiates this opinion *in the main*. There is undoubtedly sufficient lime in the *regur* soils, and most of the soils of the Gangetic alluvium contained a sufficiency; of the laterites 7 out of 12 also contained a sufficiency, and it was deficient in none of the Madras red soils. These remarks as to sufficiency and deficiency, however, are really based on a European standard, and it must be considered an open question whether it is proper to apply such a standard to Indian soils. One of the chief objects which an English farmer has in maintaining a fair proportion of lime, about 1 per cent. at least, in his land, is the retention of a sufficient amount of free basic matter to combine with the organic acids which are constantly formed from the humus. The proportion of humus in English soils is unquestionably higher, much higher, than is the case with Indian soils, and consequently it is open to doubt whether Indian soils usually are in absolute need of so large an amount of lime as one would consider necessary for English soils. Thus, I feel certain that these laterite soils, for instance, which contain so little lime, would not be benefited materially by an application of

it. On the other hand the coffee soils from the Sheveroys are somewhat differently placed. The *total* amount of lime present in them is not *very* small, but still it is not large, and most of this exists as silicate. These soils contain also a very considerably greater proportion of humus than other soils from the plains, and it *may* be that such land as this would be benefited by an application of lime.

Magnesia.—Dr. Voelcker's remark that "magnesia appears to exist in sufficient abundance throughout and more plentifully than in English soils" (paragraph 64), is amply confirmed. In the soils of the Gangetic alluvium it seems to be generally present in amount, exceeding 1 per cent. The *regur* soils contain even more than this, in two samples only did the proportion fall appreciably below 2 per cent. and in one case it ran up to 3 per cent.; indeed in these soils its amount is singularly uniform, nearly all the samples containing from 2 to 2½ per cent. The red soils contained usually about ¾ per cent.

There appears to be less of this element in the laterite soils than in the other classes referred to.

Potash.—The amount of potash was not determined in all the samples analysed, but in those which were examined for this constituent, it was generally present in very fair, or even, large amount and in those samples from the farms, the proportion of available potash was in no case deficient.

29. *Phosphoric Acid.*—From the few analyses which Dr. Voelcker had at his disposal, he concluded that phosphoric acid is "more abundantly distributed in Indian than in English soils," and he suggests that ·12 or ·13 per cent. would be a good average for English soils. Of the ten analyses which Dr. Voelcker had at his disposal, five contained more than this amount and five a little less than this. The lowest was ·09 per cent.

Among the samples which I have examined the majority contained considerably less than Dr. Voelcker's standard. Of the Gangetic alluvial soils, six contained ·08 or less, four contained from ·09 to ·13 and only two, namely, the Changa Manga soil and the calcareous one, both of which had been placed for long periods under influences of accumulation of plant food, contained more than ·13 per cent.

Of the 18 *regur* soils, 16 contained ·08 or less of this plant food, the other two containing about ·20 per cent. Of the six red soils, four contained ·08 per cent. or less, the remaining two ·09 per cent. Of the laterite soils, four contained less than ·01 per cent., four others ·08 per cent. or less and four others fair amounts. The Madras alluvial soils contained as a whole somewhat more, there being ·08 per cent. or more in six out of ten samples, but the other four contained only very small amounts. The coffee soils have doubtless been well manured, and contained with one exception ·1 per cent. or more.

Thus, as regards the amount of phosphoric acids, it is obvious that the soils of India are not abundantly supplied, but rather it must be admitted that the amount is frequently small.

Glancing, too, at the analysis of the farm soils (*vide* Chapter X), it will be seen that the land at Manjri (Poona) contained, when first taken up for the sugarcane experiments, ·03 per cent. or less of total phosphoric acid (paragraph 149), and the soil of the (new) Dumraon Farm about ·08 per cent. when first taken up (paragraph 203).

On the other hand there is one exception to the general conclusion as to the usually low proportion of phosphoric acid in Indian soils. The soils from the Meerut District contained (*vide* paragraph 36) very distinctly larger amounts of this plant food. Some of them contained as much as half a per cent., 18 out of the 35 contained ·1 per cent. or over, and only 2 contained less than ·06 per cent., but this is the only exception of any large tract of agricultural land containing ample supplies of phosphates.

30. *Available Phosphoric Acid.*—Although the knowledge of the *total* amount of phosphoric acid in a soil acts as a guide to one in forming an opinion as to the desirability or otherwise of supplying phosphates to land, still it has long been recognised that a more accurate means of judging this point would be most valuable. In 1894 Dr. Bernard Dyer of London

published an important paper before the Chemical Society, in which he showed that a close relation existed between the amount of phosphoric acid which was dissolved by citric acid, and the known fertility of certain plots at the Rothamsted Experiment Station.

An examination of a large number of the roots of plants showed that the acidity of the sap was, on the average, equivalent to very nearly 1 per cent. of citric acid, and Dr. Dyer then submitted certain of the Rothamsted soils to the action of a 1 per cent. solution of citric acid for 7 days. He took, as his standard soil, the surface soil of the field in which barley had at the time been grown continuously for 40 years. The Rothamsted experiments have yielded such uniform results that the relative agricultural fertility of the several plots was well known.

The treatment of the soil for 7 days with citric acid was admittedly empirical, but what Dr. Dyer aimed at was to demonstrate whether the results of such treatment would correspond at all with the known fertility of these standard soils.

The result of this research showed conclusively that a very close correspondence existed between the amount of phosphate thus dissolved from these soils, and their known fertility in the matter of phosphates.

A second part of the investigation consisted in answering the same question in relation to potash, and in this case likewise a close relation was made apparent between the amount of potash soluble in 1 per cent. citric acid solution, and the known requirements of the land for this plant food.

The potash and phosphoric acid in soils, which is thus dissolved by citric acid, is styled the "available" potash of phosphoric acid. Dr. Dyer examined 22 soils in this manner and he concluded from his research that "when a soil is found to contain as little as about ·01 per cent. of phosphoric acid soluble in a 1 per cent. solution of citric acid, it would be justifiable to assume that it stands in immediate need of phosphatic manure."

Although for want of time the amounts of phosphoric acid and potash rendered soluble by 1 per cent. solution of citric acid have not been determined in all the samples of soils which were considered typical of Indian agricultural land, the determination of the total and available phosphoric acid was carried out on some of the farm soils and in the case of the soils of the Meerut District. We have thus five sets of determinations of this "available" phosphoric acid, two in *regur* soil (Manjri or Nagpur) and three in the alluvium, (namely, Meerut, Cawnpur and Dumraon), and although these cannot be considered to be so fairly representative of Indian soils as those in statements Nos. 1—6, still it would seem that a conclusion may be drawn from them indirectly as to the amount of "available" phosphoric acid in some classes of Indian soils.

The amount of total phosphoric acid has been shown to be low in Indian soils as judged by a European standard. The further question now presents itself, "How much of the phosphates in Indian soils is available?"

Bearing in mind the standard which Dr. Dyer has proposed, namely, ·01 per cent. of "available" phosphoric acid, we may glance at the analyses of the Meerut and other soils in which both the available and total phosphoric acid have been determined.

Of the 35 soils from the Meerut District, only two fell below the standard. Of the samples from the field at Manjri (when taken up in 1894), only one contained appreciably less than ·01 per cent. Of the samples from the Cawnpur farm, none of those from plots, which had remained for 15 years without manure, contained so little as the ·01 per cent. limit, and most of them a good deal more; and of the soils from the Dumraon Farm, when taken up in 1895, only one contained less than the standard (namely, ·009 per cent.).

Most of the Meerut soils doubtless contain much more than an average amount of phosphoric acid and may for the moment be set aside.

The Manjri soils contained no large amount of total phosphoric acid (only ·015 to ·03) indeed very decidedly less than what *regur* soils have been shown to generally contain. The soils of the Nagpur Farm contain from ·05

to ·09 per cent. of total phosphoric acid. The soil of the new farm at Dumraon contained about ·06 to ·08 per cent. total phosphoric acid, which is much about the same as many of the soils of the alluvium have been shown to contain generally, and the soils from the unmanured plots at Cawnpur, containing from ·05 to ·08 per cent. total phosphoric acid, have also much about an average allowance. Thus, it is seen that, although the only soils in which the *available* phosphoric acid has been determined are from but a few places, the farm soils are not exceptionally rich in *total* phosphoric acid. Whilst therefore it is admitted that these are examples of soils from five particular spots, it is nevertheless evident that the percentage of total phosphoric acid in the soil of the farms is not abnormal, and that they cannot be said to be exceptional samples.

A further point may now be taken into consideration, namely, what *proportion* of the total phosphoric acid in these Indian soils is "available?" And is that proportion about the same or different from what Dr. Dyer found to be the case in the Rothamsted soils? Looking over Dr. Dyer's analyses, I see that of the total phosphoric acid in the soils of the *manured* plots, about $\frac{1}{4}$ or $\frac{1}{3}$ was "available," whereas in the case of the unmanured plots, only about $\frac{1}{10}$ of the total phosphoric acid was "available."

The Indian farm soils which have been referred to are, with the exception of one plot at Nagpur, examples of either unmanured, or at least but very *slightly* manured land, and in no case equivalent to the *manured* plots at Rothamsted; rather on the contrary do they more nearly approach to the unmanured plots at Rothamsted.

Turning now to the analyses of these soils—in those from Manjri from $\frac{1}{3}$ to $\frac{1}{2}$ of the total phosphoric acid was "available;" in the Dumraon soil about $\frac{1}{4}$ of the total phosphoric acid was "available;" in the unmanured Cawnpur Farm soils, from $\frac{1}{4}$ to $\frac{1}{3}$ of the total phosphoric acid was available; in those of the Meerut soils which contained large amounts of phosphoric acid, the proportion is very much higher; in those containing less phosphoric acid the proportion varies generally from about $\frac{1}{5}$ to $\frac{1}{3}$; in the unmanured land at Nagpur the proportion is much less, namely, only about $\frac{1}{10}$.

Thus it is seen that although most of these soils (excluding the rich Meerut soils) contained rather small percentages of *total* phosphoric acid they not only generally contain more than the standard ·01 per cent. of available phosporic acid, but also that the *relative* amount of available phosphoric acid is high.

It has been pointed out that the farm soils named are in no particular exceptional, and indeed they may be considered as fair samples of the Gangetic alluvium and the *regur* respectively; it may then be fairly assumed that in these two great types of Indian soils about $\frac{1}{3}$ or $\frac{1}{4}$ of the total phosphoric acid is generally "available." The importance of these considerations will become the more evident if reference be now made to the analyses of the alluvial and *regur* soils in statements Nos. 1 and 3. It will then be seen that if $\frac{1}{4}$ of the total phosphoric acid be generally "available," it is only rarely that we find a soil deficient in this plant food, and thus although the Indian soils have frequently or generally a low proportion of *total* phosphoric acid, it is likely that the proportion of *available* phosphoric acid is not usually deficient.

It would, of course, not be proper to assume a similar deduction for the red soils of Madras and the laterite soils, since the "available" phosphoric acid has not been determined in any soils of these two classes.

The deduction regarding the amount of *available* phosphoric acid is also quite in accord with the fact that at one farm only (namely, Burdwan) have bones been found to be of any service as manure.

At each of the other four farms, bones have regularly been applied to certain plots in the field experiments, and in no case has it been found that a materially increased outturn results from the application.

31. *Sulphuric Acid.*—Like phosphoric acid, when sulphuric acid is present in a soil, it always exists in combination with some one or other of the metallic oxides, with which it forms sulphates. There is usually no simple means of determining with which base it is associated, and for purposes of ready expression, its amount is calculated in the form of the anhydride. The majority of

Indian soils (excluding of course those which are impregnated with soda salts) contain remarkably little sulphate, and its amount was in no case as much as ·1 per cent.

Carbonic Acid.—This was determined in order to see to what extent the lime exists as carbonate. This constituent need hardly be referred to here; it has already been pointed out that its amount is usually less than sufficient to combine with the lime, and that consequently it may be assumed to be in combination principally with that base.

32. *The Organic Matter and Combined Water.*—The figures indicating the amount of these two items in the statements are in all cases the difference between the sum of the other ingredients and 100 per cent.

The loss which the soils experience on heating was determined in all cases and differed but little from the figures quoted.

Although certain deductions in some cases can be made regarding the relative proportions of the true organic matter or humus contained in the soils and the amount of the water which is chemically united with it, the knowledge of the loss by combustion of a soil does not serve as a means of even approximately determining the amount of that most valuable constituent *humus*.

It may be said, however, that in the event of any soil containing a fair proportion of organic material, the fact is readily observable to the operator who watches the appearance of the soil when placed in a receptacle over the lamp.

Referring in the first place to the amount of "organic matter and combined water" in the several classes of soils; among the alluvial soils, there are two clays which suffered a material loss, but not more than such clays would be expected to suffer, and the greater part is doubtless due to the expulsion of water; these two soils are, however, doubtless in fairly good condition, and the amount of organic matter is probably higher than in most. The soil from Changa Manga and that from Captain Chapman's doubtless contained a good deal of accumulated humus, but, as I have already explained, they have been placed under quite exceptional circumstances. All the other soils of this class undoubtedly contain but small amounts of organic matters.

The *regur* soils uniformly suffer a greater loss on heating than do those of the alluvium. I have already dealt with the question as to whether much of this may be attributed to organic matter or not in the paragraph (13) and need only say here that the amount of humus in them is probably quite as small as in the soils of the alluvium.

The loss which the red soils of Madras and the laterite soils experienced, varied very much indeed, but it will have been noticed that it is high only in those cases in which the amount of iron and alumina are also high; a similar remark applies to the alluvium from Madras Presidency, and taking into consideration the general appearance of these soils, it may be safely said that the amount of organic matter is usually very small in them. Lastly, the coffee soils from the Sheveroy Hills undoubtedly contain a high proportion of organic matter. Their appearance indicated it, the amount of nitrogen which they contain is considerably higher than in any of the other classes of soils examined, and all doubt on the point is removed by their appearance on burning.

Dr. Voelcker came to the conclusion that, with the exception of *regur*, Indian soils are deficient in humus, but even as regards *regur* he says, "That it has peculiar powers there is no question, but that it is so rich in vegetable matter and in nitrogenous ingredients as to be independent of manure I do not think."

33. *Nitrogen.*—Glancing over the figures which represent the per cent. of nitrogen in the various classes of soils, it will be seen that, with the exception of the two soils from Partabgarh and Changa Manga, and those from the Sheveroys, which cannot be considered as typical of Indian soils generally, there is in *no* case so large an amount of nitrogen as ·1 per cent. Among the soils representing the Gangetic alluvium, 3 out of 10 contain ·05 per cent. or a little more, the rest less; among the alluvial soils from Madras, two contained about ·1 per cent. and two about ·05 per cent., but in the other six

samples the proportion was much less. Of the 18 samples of *regur* soils one only contained ·05 per cent., the other 17 containing less; among the red soils from Madras one contained ·05 per cent., the other 5 less; among the 12 laterite soils not one contained as much as ·05 per cent. and most of them only about ·03 per cent. or less. On the other hand those soils which have had an opportunity of accumulating nitrogen contained very fair amounts. The soil from Partabgarh contained ·18, the surface soil at Changa Manga ·237, and the coffee soil from the Sheveroys ·04 to ·17 per cent. Thus the opinion to which Dr. Voelcker came, namely, that Indian soils are generally very deficient in nitrogen content is amply supported. Moreover, if the analyses of the other soils which are quoted in paragraphs ( ), namely, the farm soils, and those from Meerut District, be examined, the same tale is told. Among the soils from the Meerut District (paragraph 36), some of the clays contained more than ·05, but none so much as ·1 per cent., and the proportion in the more loamy soils falls considerably below ·05 per cent. The soil at Manjri (Poona) when first taken up for the sugarcane experiments contained ·035 per cent. or less (*vide* paragraph 150). The soil of the new farm at Dumraon contained about ·045 per cent. (paragraph).

34. *Special reports on particular cases.*—The following special cases relating to soils have been submitted to me:—

The first is one of some land in the Amherst District, Burma, which is thus described by the Settlement Officer.

No. 93-1—26, dated 1st April 1896.

From—The Settlement Officer, Amherst District, Moulmein,

To—The Reporter on Economic Products to the Government of India.

"I have the honour to advise the despatch to your address on the 28th ultimo a case containing certain specimens of soil and water connected with the cultivation of onions and tobacco, which would probably be of some interest.

In the neighbourhood of Yebu village, Gyaing Attaran township, Amherst, are some hot springs or tanks of boiling water, a description of which will be found in the British Burma Gazetteer, Volume I. The springs are found in low rising ground in the middle of an inundated plain, and the soil immediately round them is laterite. In the immediate neighbourhood of these tanks from which the water bubbles off on the low ground below or is carried into the river *Attaran* by a nullah, are cocoanut and betelnut plantations. The cocoanuts have the same flavour as those found near the salt water in the Gulf of Martaban. The soil is only about four feet in depth, and below that water is reached.

I send you a specimen of subsoil, No. 3, about eight inches below the surface. On the lower ground on either side the water is too deep in the rains to work any crop, but immediately the water subsides, drains are dug round the plantations and the surface soil dug up with a mamooty and the earth thrown up in ridges on which onions are planted; the crop is taken in February, and then a crop of tobacco and chillies, mixed with maize and country vegetables, is planted. The specimens now sent were taken in the month of March, while the second crop was on the ground and are, firstly a specimen of low-lying surface soil No. 1 (*b*) taken from Nga Kannas' field in which a crop of tobacco mixed with maize is planted after the onion crop was taken, and secondly, a specimen No. 2 of high-lying hard soil taken from Nga Gunnas' field in which chillies and country vegetables were planted after the onion crop was taken; about two feet to three feet below the soil, water is reached. The cultivators say that they cannot work the same soil more than five to six years continuously and not as long as that.

The soil gets worn and the crop is poor and will not produce without a long rest. I cannot, however, give any confirmation of this. They say that, if salt water is let into the fields again, it has no fertilising properties, and the land cannot be continuously worked by this means. I also

send a specimen of the boiling water from the springs No. 2 and of water taken from the drain leading past the cultivation No. 3. I should be glad if you could let me know the result of any analysis you make for insertion in the Settlement Report.

The onions grown are the small red onions and sell at R10 to R15 per 100 viss, they say, and the tobacco sells at R1 per viss, local sale. The cultivation covers only a small area."

The following report, which was subsequently submitted, explains the composition of the water and soils in question :—

"The accompanying statements contain the results of the analyses of the samples of water and soil :—

STATEMENT No. 8.

Composition of the Waters.

	$\frac{257}{96}$ No. 2.	$\frac{258}{96}$ No. 3.
	Parts per million.	
Total residue	2,750	2,780
Loss on heating	580	570
Oxygen absorbed	12	·6
Sodium chloride	5	10
Calcium sulphate	1,485	1,492
Calcium carbonate	158	133
Sulphates of magnesia and alkalis	450	390
Sand	30	60
Sulphuretted hydrogen	6	0

Considering in the first place the water, I must explain that "No. 2" and possibly also "No. 3" had changed somewhat in composition before it was analysed. No. 2 contained sulphuretted hydrogen and this substance changes somewhat easily in contact with the air. No. 3 contained no sulphuretted hydrogen when analysed, but may have contained it when put in the bottle. As the analysis shows, both waters are of practically the same composition, excepting of course in respect of the sulphuretted hydrogen, and they contain very considerable amounts of calcium sulphate (gypsum) with lesser, though still large amounts of sulphates of magnesia and the alkalis. What the exact circumstances may be under which these hot springs are formed, I cannot say. Doubtless however the sulphuretted hydrogen is formed by the action of steam and carbonaceous matter on the gypsum, and then as the water flows out of the spring and over the ground, the

sulphuretted hydrogen becomes in part dissipated, in part re-oxidised and the latter combines again to form sulphates.

STATEMENT No. 9.

Composition of the Soils.

	256 / 96 No. 3.	254 / 96 No. 1 (*b*).	255 / 96 No. 2.
Silicates and sand	21·35	59·61	65·25
Oxide of iron	28·11	2·08	1·49
Alumina	4·65	13·11	12·16
Oxide of manganese	·14	...	...
Lime	18·79	·85	·87
Magnesia	3·00	·72	·63
Potash and soda	1·06	1·51	1·27
Phosphoric acid	1·06	·06	·05
Carbonic acid	13·09	·02	·03
Organic matter and combined water	8·75	22·04	18·25
	100·00	100·00	100·00
Nitrogen	·19	·51	·41

Regarding in the next place the soils, that which is numbered three contains a very exceptionally large amount of oxide of iron, also a very large amount of calcium carbonate, and a very small proportion of silica. I conclude from the Settlement Officer's letter, however, that it is in regard to the composition of the other two soils, numbered 1 (*b*) and 2 that information is more particularly required. They are quite different from No. 3 and are of a more ordinary description. Both contain a low proportion of oxide of iron, and a high proportion of organic and nitrogenous matter; the amount of sand is low, as also is the amount of phosphoric acid. They are, I imagine, stiff clays, and difficult to work.

Excepting that the amount of phosphates is low, they are not (chemically) poor soils. But if, as I understand, the water from the hot springs flows over these lands, a reason is apparent why the people find a difficulty in raising crops on them. There is nothing more prejudicial to plant life than sulphuretted hydrogen, and if the water brings this over the land, the crops are bound to become affected.

There is, it seems to me, only one way out of the difficulty, and that is to keep this water from the springs away from the land. Whether this is possible, I cannot of course say, but if it be possible, then I should expect the land to be improved rather than injured by cultivation. It is, however, a soil which will always require good, *i.e.*, expensive tillage. It is one which requires as much exposure to the sun and air as one can give it."

DEHRA FOREST SOILS.

35. Another case of infertility was referred to me by the Conservator of Forests, School Circle.

Copy of a letter No. 287, dated 5th March 1897, from the Deputy Conservator of Forests, Dehra Dun Division, to J. W. Oliver, Esq., Conservator of Forests, School Circle, North-Western Provinces and Oudh.

"I have the honour to send herewith three samples of soil for analysis by the Agricultural Chemist. They were collected by me from the top soils of three separate places in compartments 16 and 17 in the Dholkot forests.

2. I have numbered them both inside and outside.

Sample No. 1 was collected from the top soil of an open glade surrounded by tall sâl trees, the spot being perfectly open above and within easy reach of falling sâl seeds. The spot contained no young growth.

Sample No. 2 was collected from a similar spot, but the young growth was of medium quality.

Sample No. 3 was collected from under a very thick growth of young sâl trees about 25 feet high.

3. Kindly let me know the results of the analysis."

As the following report shows, the infertility of the land was due to natural poverty of the soil.

STATEMENT No. 10.

Analyses of samples of Soils from the Dholkot Forests.

	1.	2.	3.
Nitrogen (total)	·043	·101	·152
Available phosphoric acid	·026	·028	·048
Total phosphoric acid	·105	·112	·144
Calcium carbonate	·187	·293	·685

"The soil 3 is the richest and No. 1, the poorest in plant food, and this will probably explain why the latter does not produce so much young growth."

36. *Meerut Soils.*—In 1895 Mr. Wyer, the Collector of Meerut, sent a number of samples of soil for analysis. It was impossible to make complete analyses of so many, and therefore only the proportions of the most important ingredients were determined.

The following is a copy of the report which I submitted on them, and the Settlement Officer's reply is also added :—

"I have now the honour to forward the results (*vide* Statement No. 11) of my examination of the samples of soils which were forwarded by Mr. Wyer on 15th April 1895.

The list is arranged according to the physical characteristics of the soils, and the analyses indicate that, so far as mere chemical constituents are concerned, the clayey soils are the richest in plant food, which is a characteristic of clay soils generally in other countries.

Of course any advantage which a soil may possess in respect of its richness in plant food, may be quite outbalanced by accumulations of the objectionable soda salts, known as *kallar* or *reh*.

I should feel much interested to know in how far the values which you have placed upon these soils agree with the chemical analyses.

I should have been glad to compare the analyses also with the soil map of the Meerut District which is reproduced in the last Settlement Report, but the exact places from which the soils were taken has not been forwarded to me.

For example, four samples were from Loni village, one being a grey clay, another a grey (sandy ?) soil, a third yellow *burya* usar, and the fourth a yellow sandy soil. The village Loni apparently touches two very different tracts, and therefore I am unable to tell which of these samples belong to one tract, which to the other."

Copy of letter No. 346-A.-3-5, dated 18th June 1897, from the Settlement Officer, Meerut.

"I have to thank you for the very interesting list of soil analyses sent with your letter No. 426, dated 12th March 1897, and regret that by an oversight it has been left so long unanswered.

2. It is rather difficult to answer your question, how far the value placed on the different soils agrees with the chemical analyses. These relative values vary from Pargana to Pargana and are affected by several conditions. For instance, the outstanding distinction throughout the district is that between irrigated and unirrigated, the difference being often double and never less than one-and-a-half : if nearly the whole area is irrigated in any particular tract, it is probable that there will be little difference in the rates paid for good and bad dry soils, the reason being, as I understand, that there are certain

crops which are always grown on dry soil, and the necessity of growing these forces up the rate on bad soil almost to the level of the rate on good.

3. The difficulty of answering your question is increased by the fact that the only village on your list which I have examined in detail is Dastoi, Pargana Sarawa. This is a fairly fertile village, certainly above the average and I am surprised that the analysis of the soils does not show better results; perhaps they were not typical specimens. Perhaps the best way of giving you an idea of the relative values placed on the different soils is to quote the rates at which land is actually leased in Parganas in which I find that most attention is paid to natural distinctions, Puth and Garhmuktaishur. In these Parganas the rates are:—

Best loam irrigated	₹	12	0	per acre.	
Best loam dry	„	6	0	„	
Second class loam, wet	„	9	0	„	
Ditto dry	„	6	0	to ₹1-12	per acre.
Sandy loam or superior sandy soil, wet	„	6	0	per acre.	
Ditto ditto, dry	„	3	0	„	
Inferior sandy soil, dry	„	2	0	to ₹1-4	per acre.
Clay, wet	„	9	0	„ „ 6-0	„
Do dry	„	6	0		„

These are the rates in the best villages, but the proportions are much the same, though the rates are lower, in those which are inferior.

4. The case of clay may be specially noticed as analysis shows it to be particularly rich in plant food. Here I can say without hesitation that the relative value I have given for two Parganas prevails throughout the district, dry dakar, as it is called, pays as high a rate as the best dry soil, wet dakar always pays something below the rate of the best wet soil, generally speaking about a fourth less. On the whole it is regarded as an inferior soil, and the reason no doubt is that it always lies in depressions and is liable to damage from excess of water. The reason why the dry dakar rate is high in proportion is no doubt that under normal circumstances it can produce valuable crops without water. The most distinctive crops grown in dakar are rice and gram, and although no doubt in years of deficient rainfall the rice will fail without irrigation, yet in an ordinary year it is probable that it gets as much water as it requires. Irrigation in the case of gram is of course exceptional.

5. I have looked up the old Settlement Report, but cannot find the soil map you refer to. I do not know that it would be of much assistance. There are of course tracts of extraordinarily uniform soil, witness the Parganas of Baraut, Chaprauli and Katana, or at least as much of them as is not affected by the action of water on the ravines of rivers, but as a general rule the soil varies rapidly from village to village, and it is no uncommon thing to find one village containing all gradations of soil from the most incoherent sand to the very richest loam. I do not know who selected the samples of soil, but I think the selections might have been more typical. The richest part of the district, for instance, is undoubtedly the part of Baraut, Chaprauli and Katana to which I have referred: it has been called the richest tract in the North-Western Provinces. There we have also, as I have said, a singularly uniform soil, and the analysis of a soil sample taken from any part of the tract might fairly have been considered applicable to a larger area than in the case of a sample taken from any other part of the district, but I see that you have not had a single example from there. The only village in fact of which you have a sample from the whole of that tahsil is Baghpat itself, and, Baghpat being a village on the ravines of the Jumna, with rapidly varying soils, is, in my opinion, a very bad village from which to select a soil specimen."

STATEMENT No. 11.

Analyses of the Meerut Soils.

Laboratory No.	Description of Soils.	Village.	Pargana.	Total Nitrogen.	Total Phosphoric Acid.	Available Phosphoric Acid.	Available Potash.
306—95	Grey clay	Loni	Loni	·064	·484	·340	·200
328	Ditto	Baghpat	Baghpat	·035	·131	·024	·020
323	Ditto	Sarsat Dargada	Barnawa	·064	·310	·157	·061
304	Ditto	Jellalabad	Jellalabad	·055	·146	·066	·033
308	Ditto	Dhulana	Dasna	·044	·204	·123	·068
313	Ditto	Sapnawat	Do.	·070	·110	·039	·027
318	Ditto	Shah Mohayuddinpore	Hapur	·076	·120	·045	·019
319	Ditto	Dustoi	Sarawa	·035	·069	·016	·016
316	Grey	Sapnawat	Dasna	·053	·501	·432	·068
310	Ditto	Dhulana	Do.	·051	·536	·411	·119
303	Ditto	Jellalabad	Jellalabad	·091	·544	·480	·115
296	Ditto	Loni	Loni	·038	·421	·209	·111
301	Grey usar	Jellalabad	Jellalabad	·027	·110	·041	·015
299	Do.	Dhulana	Dasna	·068	·310	·230	·070
314	Yellow usar	Sapnawat	Do.	·035	·061	·010	·014
298	Do.	Loni	Loni	·021	·142	·047	·028
305	Yellow-red loam	Sharfdin Badar Chhanwarie	Do.	·032	·151	·145	·013
307	Red do.	Ditto	Do.	·037	·067	·015	·010
311	Yellow do.	Ditto	Do.	·038	·110	·044	·016
312	Do. do.	Ditto	Do.	·041	·241	·145	·035
324	Red do.	Baghpat	Baghpat	·041	·104	·032	·042
325	Do.	Do.	Do.	·035	·061	·017	·007
321	Yellow loam	Banoli	Barnawa	·048	·068	·015	·012
327	Red do.	Do.	Do.	·034	·080	·022	·016
302	Yellow do.	Jellalabad	Jellalabad	·039	·096	·042	·042
315	Red do.	Sapnawat	Dasna	·034	·065	·011	·005
326	Grey do.	Meerut	Meerut	·037	·092	·055	·018
297	Red sandy	Sharfdin Badar Chhanwani	Loni	·023	·060	·031	·008
309	Yellow do.	Loni	Do.	·029	·068	·014	·012
330	Grey do.	Ranchhor	Barnawa	·034	·090	·062	·015
300	Red do.	Jellalabad	Jellalabad	·034	·072	·043	·011
317	Yellow do.	Shah Mohayuddinpore	Hapur	·020	·067	·027	·002
320	Red do.	Dustoi	Sarawa	·025	·047	·005	·018
329	Yellow calcareous	Baghpat	Baghpat	·033	·104	·016	·014
322	Do.	Prichhatgarh	Khator	·046	·045	·003	·008

The Chos Lands of Hoshiarpur District.

37. At the end of 1894 I received samples of soil from three places in what are known as the Hoshiarpur *chos* lands. These lands are the production of excessive deposits of sand, brought down by rivers from the Himalayas, on the top of the older agricultural soil of this part of India. The investigation was undertaken with a view to determine what difference there was between the newly-deposited sand and the older soil.

The following report which was submitted in August 1895 contains the results of the investigation, to which is added a letter from the Deputy Commissioner on the subject of how long a time is required for the newly-deposited soil to become fertile :—

Report on the composition of six samples of soils from the "Chos" *lands of the Hoshiarpur District, Punjab, which were forwarded by the Deputy Commissioner in November 1894.*

"The accompanying statement exhibits the results of the chemical analyses which I have made of the above-mentioned soils.

I have not yet had an opportunity of personally inspecting these lands, but I understand that they are subject to periodical floodings from the hill streams, and that it frequently happens that the silt left behind by the subsiding water is of a very sandy nature, so much so, that good land is frequently covered with a loose sandy soil, the latter being agriculturally inferior to the older soil.

I suggested that samples should be sent to me from different spots, of which one (in each case) should be a sample of the newly-deposited soil or what is now the "surface" soil ; the other should be a sample of the older soil which had become covered up, and which is now the subsoil.

Three such pairs of samples were sent to me by the Deputy Commissioner of Hoshiarpur in November 1894 which bore the labels "Hoshiarpur," "Dosuya" and "Garshankar," respectively, but I have not been informed at what depth the "subsoil" samples were taken. I presume, however, that these latter were not at any great depth, but are found at some 12 to 24 inches below the surface. Considering in the first place the mechanical conditions of these soils, the soils from Hoshiarpur and Dosuya were distinctly different from those from Garshankar.

Statement No. 12.

Analyses of samples of soils from the Hoshiarpur District, Punjab.

	Hoshiarpur.		Dosuya.		Garshankar.	
	(401) Surface soil	(402) Subsoil	(403) Surface soil	(404) Subsoil	(405) Surface soil	(406) Subsoil
	per cent.	per cent.	per cent.	per cent.	per cent.	per cent.
Nitrogen	·0065	·015	·0065	·023	·031	·067
Equal to ammonia	·0078	·018	·0078	·027	·037	·081
Phosphoric acid available	·015	·018	·021	·004	·038	·136
„ „ total	·080	·073	·036	·049	·069	·261
Potash available	·0092	·0215	·0069	·0065	·0499	·166
„ soluble in hydrochloric acid	·137	·461	·156	·336	·412	·979
„ total	2·230	2·809	2·917	1·845	2·422	2·529

The soil from Hoshiarpur was a light grey coarse sand at the surface, its subsoil being somewhat darker, much finer, but still sandy. The soil from Dosuya was a light grey coarse sand at the surface, whilst its subsoil was of a red colour, much finer, but still sandy. The surface soil from Garshankar was sandy, but reddish brown and much finer than the surface soils at Hoshiarpur

and Dosuya; its subsoil was very similar to it. Thus it seems that there is a similarity between the soils at Hoshiarpur and Dosuya which are, especially at the surface, much coarser sandy soils than that at Garshankar. In the statement of analyses, the pairs follow one another. Column 2 contains the results of analysis of the surface soil at Hoshiarpur; column 3 those of its subsoil; column 4 those of surface soil from Dosuya; column 5 those of its subsoil; column 6 those of surface soil from Garshankar; column 7 those of its subsoil.

In considering in what manner chemical analysis would best throw light on the respective merits of these soils, I decided to determine in each case the proportions of phosphoric acid and of potash which is *readily or immediately available* to plant life, and also in each case the *total* amount of phosphoric acid and of potash contained in them. I have also determined the amount of potash which is soluble in hydrochloric acid. This, like the proportion of "available" potash, indicates the relative extent to which these soils have decomposed.

The former determinations would thus show the relative *present* value of the soils, the latter would indicate whether the newly-deposited surface soil might eventually become as good as the older soil, if it should be inferior at the present time.

I have also determined the amount of nitrogen in these soils. There is at present no means of determining what proportion of the nitrogen in a soil is "readily available" to plants, and the figures in the statement all refer to the *total* amount of this constituent.

The further study of the figures in the statement is now simple. In the case of the nitrogen, it will be seen that in each case the surface soil contains very much less nitrogen than its subsoil, and moreover that the soils at Hoshiarpur and at Dosuya contain very much less nitrogen than that at Garshankar. The proportion of phosporic acid is not quite so regular. At Hoshiarpur the surface soil contains approximately as much of this constituent, whether readily available or not, as its subsoil. In the Dosuya samples, whilst the total amount of phosphoric acid is somewhat less in the surface soil than in the subsoil, the amount readily available is much more. In the samples from Garshankar we find considerably less phosphoric acid, both "readily available" and total, in the surface than in the subsoil.

In the case of the potash, however, we meet with greater uniformity. The proportion immediately available is much less in the surface soils at Hoshiarpur and at Garshankar than their respective subsoils; the respective proportions in the Dosuya samples are equal and at the same time very small. The proportions of potash "soluble in hydrochloric acid," which includes much more than what is immediately available to plants, are in each of the three cases much less in the surface soils than in their respective subsoils. Lastly, the proportions of total potash, though they vary somewhat among the samples, appear to be much about the same The subsoil at Dosuya contains less than the others, but this may be accidental. In conclusion it would appear generally that the surface soils are agriculturally distinctly poorer than the subsoils at present, but that they will eventually become as good. They are, in two cases especially, very much coarser, and this means that they would dry very rapidly indeed, for they will not prevent water from passing downwards, and it will also evaporate much more quickly from their surface.

The proportion of nitrogen is, as usual in Indian soils, very low indeed, but it is not lower than I should have expected.

The total amount of phosphoric acid is not high, but it appears to be generally in a readily available form.

The total amount of potash lastly is distinctly high, as is also that portion of it which is soluble in hydrochloric acid. The portion immediately available is, in all cases, fully ample for the requirements of average crops of cereals.

The most important question in relation to these soils is "at what rate do they disintegrate and decompose," *i.e.*, how soon may these new deposits be expected to become agriculturally equal to their subsoils?

If any information can be gained on this point, it would be most valuable."

Copy of a letter No. 145, dated 22nd May 1896, from Captain Inglis, Deputy Commissioner, Hoshiarpur.

With reference to your office endorsement No. 2446, dated 14th September 1895, on Dr. Leather's report on analysis of soils of Hoshiarpur *chos*, I have the honour to report that a cultivated area, converted by *chos* into pure sand, if properly planted with *kharkana* and manured with cow-dung, becomes fit for cultivation within 8 or 10 years as observed in villages Naloian, Mazian and Dual. But, as regards resuming its original fertility, it takes much longer. This period is estimated not less than 50 years.

USAR.

38. One of the first subjects to which Sir Edward Buck drew my attention early in 1893, was the usar land of the North-Western Provinces. Since then I have endeavoured to gain as much information as possible regarding the nature and quantity of the salts which are contained in usar lands, not only in the North-Western Provinces, but also in the Punjab, Gujarat and the Deccan, where a similar scourge exists.

At the time when I first took up my appointment, the amount of accurate information regarding the salts in these lands was but very slight. A map had been prepared for the North-Western Provinces, showing their geographical position, but there was no such map for the Punjab or Bombay Presidency.

The information regarding the nature and quantity of the salts was limited to the analyses of 14 samples of usar soil by Mr. Medlicott, in which however only the proportion of total salts was determined, and the nature of them not shown; two similar analyses in the journal of the Royal Asiatic Society, in which only the amount of total salts had been determined; analyses of 8 samples of soils by Mr. Ward of the Royal School of Mines, in only *one* of which had the individual salts been determined.

Field experiments for the practical reclamation of usar land had been made in the North-Western Provinces by the Agricultural and Irrigation Departments, in which tree planting had been more or less of a success, and in other cases the advantage of prohibiting grazing had been demonstrated; in one case usar land had been reclaimed by deep cultivation and liberal manuring.

In no case, however, had samples of the soil operated upon been preserved, and it was consequently uncertain whether these lands were in all cases really typical of badly affected "usar."

I have made five tours in order to see these usar lands thoroughly; in 1893 in the Cawnpur, Etawa, and Farruckabad Districts of the North-Western Provinces; in 1894 through Unao, Lucknow, Bara Banki and Bahraich Districts of Oudh; in 1895 in the Punjab, when I visited Karnal, Ferozepur, Muzaffargarh and Lahore Districts and travelled along a great part of the Chenab Canal; in 1895 in the Kaira District of Guzarat, and in 1893 along the Nira Canal in the Deccan. In addition to these tours I have frequently visited the usar reserves at Cawnpur and Aligarh where the effect of enclosure from grazing has been tested for some years on three considerable areas.

The results of my investigations, which I shall now briefly set out, have been published in detail in the Agricultural Ledger, 1897.

39. What I felt to be of first importance, was the determination of the amount and nature of the salts in typical specimens of these soils. That the amount of them on the surface varied considerably there could be no doubt, but as I have pointed out, the information regarding their nature was limited to one analysis by Mr. Ward of London, in which case the salts consisted almost entirely of the carbonate, sulphate, and chloride of sodium in about *equal* proportions.

Regarding this part of the subject I have obtained very definite information. From the North-Western Provinces and Oudh I collected and analysed

the salts in 80 samples of usar soil from 16 different places; the amounts of the individual salts were determined in 70 of these. The amounts of salts in these soils varied considerably, amounting to as much as 2 per cent. in some cases, but it was generally much less than this.

The principal salt in these soils was nearly always sodium carbonate; in only two cases did the salt consist chiefly of sodium sulphate and in no case was the amount of sodium chloride more than small. It was further shown that the greater part of these salts are situated in the first few inches of surface soil.

From the several districts in the Punjab which I visited, I collected 29 samples. In those from the neighbourhood of the Chenab Canal and from the Ferozepore and Lahore Districts, the principal salt was sodium sulphate; these soils frequently contained more chloride than was found in the North-Western Provinces usar. In the usar of the Muzaffargarh District there were about equal quantities of the carbonate and sulphate, and this usar contained more salts than I found in the other parts of the Punjab. The salts were nearly all in the surface soil.

Among the Punjab samples analysed were some from the so-called *kalrati* lands, which are commonly said to be so impregnated with salts as to be unculturable. I found practically no salts in them, and as fully explained in the Agricultural Ledger referred to, I am of opinion that the real reason why these lands are not cultivated is the fact that they are the heaviest clays in that part of the Province, and the people have found it easier to cultivate the lighter lands.

In the Kaira District of Gujarat there is a small well-defined area, which is locally called Oosar. My attention was directed to this tract by Mr. Ozanne, and here again I found conditions very similar to those of other usar tracts. Eleven samples of the soil were analysed, and in this case I found that the principal salt was sodium chloride; the carbonate and sulphate were also present, but in subordinate amount. Here again the salts were situated chiefly in the surface soil.

From the country in the neighbourhood of the Nira Canal in the Deccan, which has become seriously water-logged by leakage from the canal, and where salts have also accumulated, I analysed five samples, in four of which the principal salt was the chloride, in one the sulphate. Sodium carbonate was absent from all these soils. Thus it is evident that not only does the amount of these sodium salts vary considerably, but that it is not always the same salt which predominates; in some cases it is the carbonate, in others the sulphate, and in yet others the chloride.

40. *The amount of salts in good soils.*—In addition to the analyses of usar soils which have been thus briefly referred to, I determined the amount of these soda salts in 11 samples of good soils and clays, in order to determine what quantity was usually present, and the result of these analyses showed that, although in some cases there might be as much as ·1 per cent. of total salts present, there is usually much less than this, ·02 or ·03 per cent. of total salts being common. All three salts were found in four out of the 11 samples. Sodium carbonate was found in 7, sodium sulphate in 5, and the chloride in 7.

41. *Pot cultures.*—In 1895 and 1896 I attempted to determine how much of these sodium salts might be present in a soil without preventing plant growth. To good garden soil, which was shown to contain no appreciable amount of any of the salts, were added definite amounts of the three salts *singly*, *i.e.*, one series of soils were prepared containing varying amounts of the carbonate, another set contained the sulphate, whilst a third contained the chloride. The amounts of salt which were added, varied from ·1 up to 1·0 per cent. It was found that each of these salts retarded the germination; the cereals were affected in this way by ·7 per cent. of sodium carbonate or sulphate and by ·4 per cent. of chloride; the germination of the leguminosæ was affected by smaller amounts than the above, ·2 to ·4 per cent. of the carbonate or chloride and by ·7 per cent. of sulphate.

In the after-growth ·2 per cent. of the carbonate certainly did harm in the majority of cases; whilst ·4 per cent. was quite fatal.

The effect of the chloride was not quite so uniform; in the first experiment ·1 per cent. proved harmful, but in the second series of experiments some of the plants grew perfectly well in the presence of ·2 per cent. Sodium sulphate proved to be less harmful than either the carbonate or chloride, and in both the *kharif* and *rabi* seasons of 1896 perfect growth was maintained in the presence of ·5 per cent. of this salt. As in the germinating stage, so also in the after-growth, the leguminosæ were affected by smaller quantities of any of the salts than were the cereals.

The results obtained by these pot cultures are more or less substantiated incidentally by the known fertility of some of the samples which I had collected on tour.

42. *The effect of gypsum on usar soils.*—One very common peculiarity of these usar soils is their impermeability to water. If a good soil be mixed with a considerable volume of water and the muddy liquid be then poured upon a filter, the water-extract will come through rapidly.

For example, in order to separate the sodium salts from the usar soils, they were mixed with five times their weight of water, and after standing, the whole was poured upon a filter of about 4″ or 5″ diameter, with a fall of about 8 feet of water to increase the speed of the filtering process. In the case of good soils, the whole of the water usually came through in a very few minutes, whereas the aqueous extract of most of the usar soils took hours or even days to pass through. So likewise, if some good soil or clay be mixed with water in a cylinder and allowed to stand, the whole of the soil settles out fairly rapidly, whereas the usar soils usually remain suspended even after standing at rest for weeks. The effect of small quantities of gypsum, and some other salts such as calcium chloride or barium chloride on these usar soils, is very remarkable. If to one of these muddy liquids (of usar soil), which has refused to settle after standing, a small quantity of gypsum be added, and the vessel shaken thoroughly, it will be found that the soil particles have curdled together, and that they will now rapidly subside, leaving a clear liquid above; or if poured upon a filter, the water passes through rapidly, as in the case of ordinary soils. The effect of calcium chloride and barium chloride is similar. (Other salts, such as sodium chloride and sodium sulphate, will also cause the precipitation of these soils, but in this case the quantity of salt necessary for the purpose is very much greater and the solutions require to be concentrated). It occurred to me that the peculiar impermeability of these soils to water was due to the sodium carbonate present.

If so, the coagulating effect of the gypsum or other salt would be due to their neutralising the sodium carbonate, and the amount of gypsum or other salt required to coagulate these soils would be equivalent to the sodium carbonate present. In order to test this point, I carried out a series of quantitative experiments, the result of which was to show that a very close relation does really exist between the amount of calcium sulphate, calcium chloride or barium chloride, required to cause the coagulation of these soils, and the amount of sodium carbonate present.

The practical value of these experiments is very great, for not only do they show that an application of gypsum to some usar land, would cause the pernicious sodium carbonate to be converted into the less harmful sodium sulphate, but also that, whereas these soils are at present so impervious to water that the process of natural drainage is impossible, or only very slow, gypsum (of which there are large quantities in the Himalayas and other parts of India) would open them up to the passage of water, and natural drainage conditions would be again created. The result of the latter would, of course, be the more or less rapid withdrawal of the salts *en masse* from the surface soil to the subsoil water.

This part of the work was only done this year. I have informed the Director of Land Records and Agriculture, North-Western Provinces and Oudh, of its importance, and a quantity of gypsum has been obtained and is being applied to some of the Aligarh land.

43. *The effect of enclosing usar land from grazing.*—In 1885 two areas of bad usar land, measuring 718 and 241 acres, respectively, were taken up at

Aligarh by the Agricultural Department, and several experiments for the practical reclamation of usar land commenced. The chief of these consisted in simply keeping the grazing cattle off.

The immediate result of this was the spread of grasses all over the two reserves. The land has not, however, become fertile, and although trees have succeeded here and there on them, crops have generally failed *up to the present.*

I have analysed a number of samples of soil from certain spots on both these reserves, and in all cases the salts have been found to be distributed through some 3 to 6 feet of soil, whereas, as has been already pointed out, in ordinary usar land the salts are principally situated in the first few inches of surface soil. It would thus appear that another effect of exclusion from grazing is to cause the salts to become gradually distributed through several feet of soil instead of being concentrated in as many inches.

Reclamation for Ravine Lands.

44. I have taken such opportunities as have offered of inspecting reclamation works of the above-mentioned nature, and I have described three methods of dealing with such land (*vide* Agricultural Ledger No. 16, 1894). Although in many parts of India, especially in parts of Madras and Bombay, the people habitually protect their land from erosion by surface drainage, in others (I have noticed it especially in the North-Western Provinces and Oudh) such care is frequently not exercised.

That a great deal of valuable land is being gradually lost in this manner there can be no doubt. For example, I met with a case last November when in Oudh, in which field after field in one village had been gradually cut away by surface wash.

Where any large area of ravine land has been formed, such as for instance is the case more especially in the neighbourhood of the Jumna, the reclamation of it should form most useful famine work. But in individual cases of surface erosion occurring in villages, it is probably often impossible for Government to do anything. In the first place the damage might not be reported. Then, too, conflicting personal interests sometimes play a part. In the case above referred to, I believe that the people know perfectly well how to stop the erosion, but, so far as I could learn from enquiry, the village was owned in part by a number of different people, who, as usual, would not agree to do the necessary repairs jointly.

Special Managers of Wards' Estates, for example, would do well to watch very carefully for this damaging effect of surface erosion. It is not only desirable to correct the evil after it has established itself, but of greater importance still to prevent it from ever occurring.

The Exhaustion of Indian Soil.

45. The question whether the soil of India generally is becoming exhausted has been raised and discussed by more than one person, and is the somewhat natural outcome of the fact, which is at once brought to the notice of any one who visits India, namely, that a large part of the cattle manure is used as fuel. Clearly, on the face of it, if "exhaustion" be taking place, it is a slow process, and strictly speaking one could only determine the matter by very careful observation and experiment carried on for a long period. It will be equally clear that it would have been impossible for me, in the few years at my disposal, to attempt such a series of experiments. At the same time, since I have had an opportunity of spending several years in India, it will not be out of place if I set out very briefly the views on the subject which I have come to hold, views I may observe which are in most respects in accord with those expressed by Dr. Voelcker, but to which I shall add something.

46. In the first place it will be well to refer for a moment to the opinion which Professor Wallace of Edinburgh (who spent 4 months in India in 1885 or 1886) expressed in his book entitled "Indian Agriculture." He says (Chapter 13, page 158)—"One old and very important question with regard to India still continues to be asked: Is the fertility of the soil being exhausted by the native practices that have been going on for thousands of years? My unqualified answer is No." He then proceeds to explain what he refers to under the term "soil," and describes in detail the process of surface washing which occurs

annually throughout India. He concludes the paragraph with the words: "By cropping in the ordinary way the native fertility of a soil cannot be lowered."

The succeeding paragraph, however, makes an all-important explanation of what Professor Wallace means by "native fertility." "Temporary fertility, the qualities possessed in virtue of some accumulation of material useful to plants, may be dissipated, but when this is gone, no system of cropping can reduce the land to a lower point. The greater portion of the land in India which is not newly broken in, annually produces its minimum yield. Where declining fertility has been recorded, it was no doubt due to loss of temporary fertility which had accumulated during a period of rest." This second paragraph then contains the all-important admission that, although the fertility of Indian soils is not being exhausted, still it can become more fertile by rest, and that formerly it contained a store of *temporary* fertility which has now gone, and that the land has reached a certain level below which it cannot descend.

I may here observe, with regard to the distinction which Professor Wallace makes between *temporary* and *natural* fertility of soils, that it is one which no other authority on agricultural subjects (so far as I am aware) has assumed, and it is clearly only a question of *terms*. The *natural* fertility of a soil, which Professor Wallace says, cannot be destroyed, certainly includes more than the mere rocky particles of which a soil is composed, for some organic matter is certainly also a component part, and how one is to distinguish between this portion of organic matter belonging to the *natural* fertility on the one hand, and that other portion of organic matter which belongs to Professor Wallace's *temporary* fertility on the other, is a problem which it is quite impossible to solve, since they both are the product of the decay of plants or parts of plants in the soil.

The presence of a store of "temporary" fertility in the past may or may not be the case; the opinion that a soil cannot be reduced in fertility below a certain level is one for which there is absolutely *no* proof; on the other hand, we have the *fact* that in the Rothamsted and Woburn experimental fields in England, the crops, which have been grown for so many years without the aid of manure, *do* annually become less and less, and the limit (if there be one) has not so far been reached.

47. This fact is pointed out by Dr. Voelcker, and he further examines three questions which have a close relation to the main one. The first is "how much nitrogen is added to the soil by the rain?" The rainfall at Rothamsted brings annually about 4·5 lbs. of nitrogen per acre to the land. For some time it was contended that the rain in India brought very much more than this, and figures, which afterwards proved to be erroneous, were quoted in support of the fact. Later determinations by Dr. Van Geyzel of Madras showed in 1888 4 lbs., and in 1889 only 2·1 lbs. per acre of nitrogen to have been so deposited; later in 1891 Mr. Bamber, then Chemist to the Indian Tea Association, Calcutta, found that the nitrogen in the rainfall at Calcutta from May to October was equal to 3·4 lbs. ammonia. Thus then it is practically certain that no large amount of this all-important plant food is added to the soil from this source.

48. The second point which bears upon the question is, "What is the effect of growing such large quantities of pulses and other leguminous plants in India? What amount of nitrogen is supplied indirectly by this means to other crops?" Unfortunately there is no answer to this question at present. All that one can say is that, knowing as we do, that the members of this natural order *do* assimilate atmospheric nitrogen, they *are* a means of adding this plant food to the soil, and doubtless it forms a very important item in relation to Indian agriculture.

49. The third point which has been brought into the discussion, is the effect of the export of grain, oilseeds, and bones from India. Dr. Voelcker considers, as others have done, that this forms a serious loss (paragraph 51).

He says (paragraph 51)—

"On the one hand there is large export of oil-seeds, cotton and other products, besides an increasing one of wheat, all of which remove a considerable amount of the soil constituents. What is returned in their place? Only the straw or the stalks and leaves; and it is not even correct to say that these are returned, for, after all, it is only a portion, and

frequently a very small portion that does find its way back to the soil. Part is necessarily used up in the bodies of the cattle, part is wasted by imperfect conserving and storing of manure, part must unavoidably be lost, however great the care that may be taken; thus it comes about, that it is only a fraction that contributes finally to making up the loss the soil has sustained, Were, on the contrary, all grain to be consumed by the people, and all night-soil to be used in agriculture; were all refuse of oil-seeds (after pressing out the oil) to be utilised for manure; were all straw to be consumed by cattle and the droppings, solid and liquid together, to be carefully preserved; lastly, were all stalks and leaves to be buried again in the land; then the balance might be more nearly preserved. But, as things are, the exports of oil-seeds, grain, etc. (that of bones I will discuss later), simply mean so much of the soil constituents carried off for which no adequate recompense is made.

50. To my mind this matter of export of agricultural produce has been gauged as far more serious than a consideration of the facts of the case will allow. In the paragraph just quoted from Dr. Voelcker's Report he says, that if the residual matters of the crops produced in India were returned to the soil, the balance would be maintained, and it is clear that one may take this to be a fundamental fact. But it is also clear that export of agricultural produce out of India can only become a serious item *when it removes a material proportion of the plant-food which is extracted by each crop.* Now what is this proportion?

In a paper entitled, "Memorandum on the resources of British India," Dr. Watt makes an estimate of 57,215,000 tons as the production of food-grains, which, however, Dr. Watt does not consider very accurate. I, myself, think it may be somewhat too high. Nevertheless it is not so utterly wrong as to be worthless for the purpose in question.

The total exports of food-grains is about 2,500,000 tons, or roughly 5 per cent. of the production, and accordingly some 5 per cent. of the plant-food, which the grain of the crops annually extract from the land, is exported.

Now what is the amount of plant-food which the Indian grain crops take up to form their substance?

If we allow it to be some 15 lbs. of nitrogen and half that amount of phosphoric acid per acre (which are the only items that need be taken into account), such an estimate cannot be considered too low; indeed it is in all probability too high. This is the amount moreover which is taken up by the whole crop (straw included). Since only grain is exported, it follows that it is not 5 per cent. of the above-named quantity, but 5 per cent. of a still smaller figure (probably $\frac{2}{3}$ or $\frac{3}{4}$ of it), which would represent the drain of these plant-foods per acre caused by export, or, in other words, it will not be much more than half a pound of nitrogen and a quarter of a pound of phosphoric acid per acre per annum, and may be, it is less than this. Such quantities as these are in all probability amply replaced by nature.

A similar result is obtained, if one calculates, from the known amounts of nitrogen and phosphoric acid in the exported grain, the amount of these substances per acre. But by deducing the figures in the manner adopted, it is more clearly brought out how small a proportion of materials, required for the grain crops of India, are thus taken out of the country.

It has already been mentioned that the rainfall brings down annually several pounds of nitrogen per acre, and this agency alone much more than makes up for the loss of this element caused by export. And, in the case of phosphoric acid, the annual movement of silt from higher to lower ground by the monsoon rainfall, must be admitted to be a source of mineral plant-food.

Thus, there can hardly be any doubt that the export of food-grain from India has been considered to be a far more serious drain than it really is.

And, similarly, in the case of bones, quite apart from the fact that, at only one of the five experimental farms has this material been found of any value as manure, if the amount of phosphate exported be referred to the acreage, it will be at once evident how utterly impossible it is that this trade can be exercising any influence on the fertility of the land.

51. It is much more important to consider how the fertility of the land can be increased, than to consider whether the land is becoming "exhausted." "Exhaustion" is a purely relative term; it is highly improbable that in any

process of agriculture a certain level is finally reached, below which fertility cannot descend, and it would be much more correct to say, the fertility of the land in India is not only low compared with that of other countries, but that if it is not *decreasing*, it is certainly not *increasing*. It must also be admitted that with a better supply of manure, that fertility would be *immediately* increased and more grain produced per acre.

And for that better supply of manure there is only one principal source namely, the *dejecta* of the human beings and animals that consume very nearly the whole of the grain crops, straw included. It is in the more perfect *direct* (not indirect) return to the land of these matters, that one can look for an increased manure-supply, an increased fertility, an increased outturn of food-grain. Doubtless, under present circumstances, there are many difficulties to be overcome before anything like great economy will be realised in this direction. There is the scarcity of fuel which occasions the loss of nitrogen and organic matter of a very large proportion of the dung of agricultural animals; there is doubtless a great deal of carelessness among cultivators (more in some parts than in others) as to the preservation of such refuse materials as are not burnt; there is a similar want of method practised in relation to the night-soil. These difficulties may some day be removed. In the meantime they remain an acknowledged fact, and that but for these obstacles the land *would* be more productive than it is. Further, so far as nitrogen is concerned, it may be kept in mind, that of the other two sources of this element, the rain is annually giving several pounds per acre, and that the leguminosæ are also beneficial in a like direction. But to what extent they are thus beneficial is a problem which remains for future investigators to determine.

CHAPTER II.

WATER.

52. In relation to the chemical composition of the water as obtained from one or another source in India, I have made only two definite investigations.

The one had reference to the amount and composition of the silt carried on to the land by the Upper Eastern Jumna Canal and this work is dealt with in Chapter III (*vide* paragraph 80).

The second investigation had reference to the composition of certain well waters in Gujarat, Bombay Presidency, which had a reputation for being particularly suitable for tobacco cultivation. The results of this work have been published in Agricultural Ledger No. 14, 1895.

In addition to these subjects, I have, when on tour, taken some samples of well and other waters in villages and append the results.

53. *Gujarat Well Waters.*—The enquiry into the composition of the well waters of Gujarat was taken up at the request of Mr. Ozanne, then Director of Land Records and Agriculture, Bombay. Mr. Middleton, then Professor of Agriculture, Baroda, accompanied me, and assisted me in finding out some of the villages where these peculiar wells are situated. The country in which these wells are principally met with is the Charotar, and here it is that large areas are utilised annually for tobacco cultivation.

In the immediate neighbourhood of some of the villages of this country, there are wells, the water of which the people call "salty," and which they value highly for tobacco cultivation; there are also wells containing water which is called "sweet," and which, though frequently likewise used for tobacco, is nevertheless not considered by the people to possess any particular virtue. These two sorts of wells are moreover frequently situated close together.

At one village, Petlad, for instance, there were two wells in one field, about 200 yards apart, the one being a "sweet," the other a "salt" well, and at village Durmuj a similar case was met with. The "salty" water is sometimes considered too "salt" for application to the crop in the *undiluted* state, and in such cases water is drawn simultaneously from the two descriptions of wells, run together into one channel, and applied to the land in the mixed state.

The value of the "salt" wells is very great, and is either auctioned annually, or sold by the owners in quantities which are measured by counting the number of buckets drawn up.

The "salt" wells are not as a rule at any one side of a village, but are distributed apparently at considerable intervals. In one village, Durmuj, however, I found a most extraordinary collection of these "salt" wells, no less than 20 being situated within an area of 9 bighas (2 acres). They were not all considered equally "salt," nor did they all supply equal quantities of water. One, for example, which was formerly considered the best, was nearly dry at the time of my visit, whilst three or four other wells at a distance of only a few yards contained plenty of water. The ground was somewhat uneven, but so far as I could tell, the water in all (excepting the dry one) appeared to be at about the same level. The measurements from the surface of the water were 50, 54, 54, 57 feet, whilst the dry well was curiously the deepest of all, namely, 60 feet.

Samples of the water from particular wells, some of which were named "sweet," others which were considered "salt," were collected and analysed. The analysis readily showed in what particulars these well waters differed from one another. The so-called "salt" water contained large quantities of sodium chloride and sodium or potassium nitrate, besides salts of lime and magnesia. The amounts of the several salts varied very considerably. The largest amount found was 8,221 parts sodium chloride per million (575 grains per gallon) and 1,948 parts nitric acid, equal to 3,637 parts of potassium nitrate per million

(136 grains nitric acid or 254 grains potassium nitrate per gallon). The smallest amount of these two salts in any of the "salty" waters was 285 parts sodium chloride per million (20 grains per gallon) and 153 parts nitric acid, equal to 285 parts potassium nitrate per million (11 grains nitric acid, equal to 20 grains saltpetre per gallon).

There was just as great variation in the composition of the so-called "sweet" well waters. In one case such water contained 94 parts of nitric acid, equal to 176 parts saltpetre per million (or 6·5 grains nitric acid, equal to 12 grains saltpetre per gallon), whilst the water of another such well contained only 11 parts of nitric acid, equal to 21 parts saltpetre per million (·77 grains nitric acid, equal to 1·47 grains potassium nitrate per gallon).

54. The residues obtained by evaporating these waters were all analysed, and it was found that, although potash was present in some of them, it was absent from others, and, as a matter of fact, the three waters which contained most nitrate, contained no potash. In the paper alluded to the nitrate was expressed in terms of the potassium salt, because it was thought that the lack of nitrate in the water of some of the villages might be made up for by purchased saltpetre, this being the only nitrate commonly obtainable, and it was therefore convenient to show how much saltpetre would be required to supply the deficiency.

Samples of the soil of some of the tobacoo fields were selected and analysed. The composition was remarkably uniform. The soils of the Charotar consist of a beautiful loam, which is sometimes a little sandy. The amount of potash was in nearly all cases about half a per cent. The phosphoric acid varied from ·22 to ·42 per cent. and was higher than in some land of the same neighbourhood.

The proportion of nitrogen varied from ·034 to ·061 per cent. which was less than one might have anticipated.

From some data supplied to me by Professor Middleton, I was enabled to make the following estimate of the amount of nitrate (calculated as potassium nitrate) which is supplied to the tobacco by some of these well waters.

"Irrigation is continued for about 100 days each season. At the beginning of the season the salt wells may supply 15,000 to 20,000 gallons of water daily; towards the end of the season not more than half of this quantity will be obtainable. The water of the three best wells is mixed with the water of the surrounding brackish wells during irrigation in the proportion of about one to four, and in one watering, an acre may get about 50 tons of the salt (water) and 200 tons of the brackish water (this is about the quantity raised, 15 to 30 per cent. may be lost before the water reaches its destination). The salt water is only used *once* on each field during the season, but tobacoo is irrigated from the other wells from 5 to 8 times, altogether the land will get 50 tons salt and 1,000 to 1,600 tons of water from brackish and inferior salt wells in a year."

"Thus leaving out of account any nitrate which may be contained in the other wells and allowing only for that in the water of the best wells, we may take it that 50 tons of such water as those marked "Durmuj," "S1" and "S2" are given to an acre of tobacco. There is a very considerable difference between the amounts of nitrate in these two samples, and I have but little doubt (since the wells are situated close together) that the proportion of nitrate will vary even in the same well during the season; hence if we take the mean of the two analyses as representative of the average quality of these waters, we must bear in mind that it may be an over-estimate of the truth. The mean is 2,268 parts per million of water; 50 tons will, therefore, contain some 254 lbs. of nitrate of potash."

"If the estimated 1,000 to 1,600 tons of the other water contain an amount of nitrate in any way approaching that of the sample No. 156—95, it will be seen that this water will contribute an amount of nitrate about equal to that in the 50 tons of "salt" water, and the application of nitrate becomes double that above stated, namely, some 500 lbs. per acre."

Naturally one must use some discretion in making such estimates as these, but it would seem well worth the while of cultivators in such villages as Bhadran, where their well waters are not possessed of the peculiar features of those in villages Durmuj, Petlad, etc., to find out if it will pay them to buy

some saltpetre and apply it as a top dressing to their tobacco crops at the time of irrigation.

55. *Composition of well, canal, and tank waters.*—In addition to the foregoing investigation I may here add the partial analyses of some samples of well, canal, and tank waters which I have collected from time to time when on tour, and which have not been published hitherto.

Of the samples in the two statements Nos. 14 and 15, those which are marked with an * are situated within usar areas, and were selected to see if these waters contained any particularly large quantities of salts. It will be seen that the residue varies very greatly both in amount as likewise in composition. Many of them are strongly alkaline, due to the presence of sodium carbonate. The total amount of salts in them is in some cases much larger than in well waters from areas in which there is no usar. The samples 435, 437, 439 and 441 of statement No. 16 are from villages quite free from usar. The amount of nitrate in these well waters is not very great. In one case it approaches 10 grains per gallon, but in the others there is only about one grain or so.

The three samples Nos. 278, 279 and 280—94 of statement No. 15 are what is locally called *chopdu*. This *chopdu* water is well known in Gujarat and is a subject well worth investigation. So far as one can learn from simple enquiry it is a case of certain well-waters containing so much salts, that to employ the water for irrigation is to seriously affect the fertility of the land. I was shown an orchard, for instance, which the people said had been seriously damaged by irrigation from a certain well.

Of the three samples analysed, No. 278 at village Wanghi was called *chopdu*. It contained 83 grains per gallon of solid residue, which was alkaline with sodium carbonate and contained a good deal of common salt. The other sample, No. 279, from the same village was styled "*chopdu* but sweet." It contained 280 grains per gallon of solid residue, the greater part of which consisted of chlorides of magnesium, sodium and potassium, but there was no carbonate. The third sample, No. 280, from another village of the same locality, had an even larger amount of dissolved salts, and here again they consisted principally of chlorides of magnesium and the alkalis. It is a most unusual thing to find magnesium chloride in well waters at all, and two of these are essentially different from the third, although they are all styled *chopdu*. Also it is to be noted that these *chopdu* wells are situated in the black soil area where there is no usar.

STATEMENT No. 13.

Composition of some Canal Waters.

	Grains per gallon.		Composition of residue.
	Total solid residue.	Chlorine as sodium chloride.	
69—93. Ganges Canal . .	10·08	·66	Principally calcium carbonate.
73—93. „ „ . .	12·04	·82	Ditto ditto.
128—93. Raspanna Canal (Dehra Dun).	74·04	·33	Hardness 31½. Principally calcium and magnesium sulphates.
224—93. Canal at Lahore .	13·16	·68	Principally calcium and magnesium sulphates.
282—94. Nira Canal (Deccan)	7·28	·48	Ditto ditto.
283—94. Baramati Canal (Deccan).	1·008	·48	Ditto ditto.

STATEMENT No. 14.

Composition of Water from certain Lakes and Tanks.

	Grains per gallon.		Composition of residue.
	Total solid residue.	Chlorine as sodium chloride.	
70—93. Lake at Reori (Cawnpore District).	13·44	·98	Mostly calcium carbonate; some magnesium sulphate.
*72—93. Tank at Maw (Cawnpore District).	23·80	4·26	Principally sodium carbonate with small quantities of lime and magnesia.
*77—93. Tank at Shiuli (Cawnpore District).	39·20	1·97	Mostly sodium carbonate and sulphate, with lime and magnesia.

* *N. B.*—These tanks are in the neighbourhood of usar land and have become impregnated with sodium carbonate carried by the surface drainage.

STATEMENT No. 15.

Composition of Well Waters.

	Grains per gallon.		Composition of residue.
	Total solid residue.	Chlorine as sodium. chloride.	
*67—93. Well at Tirwa (Farrukhabad).	30·80	2·14	Contained a lot of organic matter. Residue very alkaline; principally sodium carbonate and magnesia.
*68—93. Village Bandhmau (Etawah).	44·80	6·23	Residue very alkaline; principally sodium carbonate; little lime and magnesia.
*71—93. Village Mau (Cawnpore).	69·72	16·56	Residue slightly alkaline; principally calcium and magnesium carbonate and sulphate.
*74—93. Village Bhausana (Cawnpore).	35·23	2·78	Residue very alkaline; principally sodium carbonate; little lime and magnesia.
*75—93. Village Biti Bikru (Cawnpore).	65·24	5·74	Residue very alkaline; principally sodium carbonate and sulphate with some magnesia; little lime.
*76—93. Village Shiuli (Cawnpore).	289·24	128·57	Residue slightly alkaline; besides the sodium chloride, there were considerable quantities of calcium and magnesium sulphates, with less carbonate.
*80—93. Village Bhagwat (Cawnpore).	203·0	50·84	Besides the sodium chloride, this residue consisted principally of magnesium sulphate and carbonate.
*81—93 Village Amri (Cawnpore).	157·64	47·23	Besides the sodium chloride, the residue consisted principally of magnesium sulphate.

STATEMENT No. 15—*contd.*

Compositions of Well Waters—contd.

	Grains per gallon.		Composition of residue.
	Total solid residue.	Chlorine as sodium chloride.	
*82—93. Village Champatpur (Cawnpore).	146·16	33·13	Besides the sodium chloride, the residue consisted principally of magnesium and calcium sulphate and chloride.
*225—93. Lahore gardens (Abyssinian well).	39·76	5·76	Principally calcium and magnesium sulphate.
*226—93. Lahore gardens (well).	86·52	21·01	Besides the sodium chloride, the residue contained large quantities of sodium carbonate, and sulphate and some magnesium carbonate.
278—94. Village Wanghi (Surat District).	83·44	18·39	This residue was very alkaline and besides the sodium chloride, there was a good deal of sodium carbonate and magnesium carbonate
279—94. Village Wanghi (Surat District).	280·0	...	This residue, when heated evolved hydrochloric acid, and it was therefore further examined. It contained magnesium chloride 90·78, potassium chloride 22·40, sodium chloride 82·60; there were no carbonates, but a little sulphate.
280-94. Village Wed (Surat)	374·36	...	This residue also gave off hydrochloric acid when heated, and consisted principally of magnesium and alkali chloride; some lime, some sulphate, but no carbonate.
275—93. Surat Farm, I .	111·4	61·32	Besides the sodium chloride, the residue contained principally sodium sulphate and magnesium carbonate.
276—93. Surat Farm, II .	61·88	37·75	Ditto ditto.
277—93. Surat Farm, III .	107·5	72·60	The residue had a similar composition to the other two, but contained in addition a good deal of calcium carbonate.

STATEMENT No. 16.

Composition of certain Well Waters.

	Grains per gallon.						Calculated.	
	Lime.	Magnesia.	Alkalis.	Sulphuric acid.	Chlorine.	Nitric acid.	Sodium chloride.	Potassium nitrate.
*433—94. Banthra (Lucknow)	5·04	7·28	8·68	...	·84	...	1·4	...
435—94. Satrikh (Bara Banki)	8·75	12·04	9·59	3·36	7·84	5·04	12·81	9·33
437—94. Kaisargunj (Bahraich)	9·10	1·12	31·92	2·17	2·59	·49	4·27	·91
439—94. Bahraich	7·70	4·20	8·19	...	1·75	·63	2·87	1·19
441—94. Kashwarpur (Bahraich)	6·09	5·88	3·01	·49	·84	·28	1·40	
135—95. Lasundra (Karia District)	3·29	2·80	24·22	2·87	10·01	·91	16·38	1·75
*136—95. Lasundra („)	29·33	32·20	132·72	7·70	190·05	1·68	312·69	3·22
134—95. Ajupura („)	6·86	7·28	2·03	...	3·43	...	5·67	...

These analyses of well waters agree uniformly in one respect with that which Dr. Voelcker analysed, and referred to in paragraph 99 of his report. They all contain much more salts than do the canal waters.

56. Among the six waters selected from *canals* and detailed in statement No. 13, only one, that of the Dun canals, contained any large amount of salts. The Dun canals are fed from the hill streams and contain a lot of sulphate and carbonate of lime and magnesia In the case of the other canals, the amount of salts is only about 10 or 12 grains per gallon.

57. The composition of the water in *lakes* and *tanks* very naturally varies according to circumstances. The one at Reori, although in the neighbourhood of usar, is so large that surface drainage has not impregnated it with salt to the same extent as were those at villages Mau and Shiuli, also situated in the neighbourhood of usar, but which were much smaller.

58. *The Temperature of Indian Well Water.*—The temperature of well water in India is somewhat striking, since it usually feels distinctly warm to the hand. I have never met with one which felt cold. When on tour I have frequently taken the temperature of the water in these wells, in part to find out what the temperature really is; in part also because the common idea is that the temperature varies, that it is hot in the morning, cool at midday, and warmer again in the evening.

This idea is manifestly the outcome of the varying temperature of the skin, this being higher at midday. That such a large volume of water as is commonly found in wells could alter in temperature during a few hours, is of course physically impossible, and, as a matter of fact, in the case of those wells examined for the purpose, there was no difference observable in the temperature.

I thought it might be however that in the case of fairly wide wells in which the water is not far from the surface and thus exposed to the sun, the surface layer of water might become heated during the day, and for this purpose, I have frequently taken the temperature at the surface and at the bottom of wells, with a self-registering thermometer; but, there was practically no difference in temperature, in one case only out of twelve was the surface water warmer than that at the bottom, and in this case there was a difference of 3°F. Among the others the water at the bottom was frequently a little warmer by 1° or 2° F. than the surface. The temperature of the well waters is indeed remarkably uniform.

In the shallow wells (5 to 25 feet to water) the temperature in the 31 cases which were tested, with four exceptions, varied from 69° to 75°F; one had a temperature of 66°, whilst three others had a temperature of 76° to 78° F., respectively.

In the deeper wells in which the distance to water was 40 feet and upwards, the temperature of the water was distinctly higher, and ranged from 79° to 82° F., and this regularity in the temperature is moreover observable quite irrespective of the locality. It apparently applies alike to wells in Gujarat and in the North-Western Provinces.

CHAPTER III.

MANURE.

59. In Chapter 7 of Dr. Voelcker's Report the subject of the supply of manure in India is discussed.

In the first place, Dr. Voelcker points out that the so-called "artificial" manures, which occupy such an important place in English agriculture, can find, owing to their cost, but a very limited one in India, and that what is of immediately pressing necessity is to have applied to the Indian soil the natural manures which are available throughout the land.

Speaking of cattle manure, he produces evidence that it is by no means of poor quality; that an enormous loss is experienced when it is burned, and that the urine, so generally wasted at present, should be preserved. In fact, he sums up the chapter on manures by expressing the opinion that to save the cattle dung is the most important item.

In relation to the night-soil, Dr. Voelcker emphasises the necessity for adopting measures to get it likewise on to the land and, where necessary, to illustrate to the cultivator its value as a manure. He says, "I regard the spread of a good system of utilising human and household refuse, street sweepings, etc., on the land as a most potent factor in the improvement of Indian agriculture."

He also enumerates other materials which must be considered as valuable fertilisers, such as oil-seed cakes, indigo seet, green manures, refuse leaves and twigs, silt, bones, and nitre.

Finally, Dr. Voelcker concludes the chapter by expressing the opinion that the most important item in the manure-supply of India is the cattle manure, and that it is a positive duty of Government to endeavour to find a means of supplying wood fuel in order to save the dung from being burned.

60. During the five years which I have spent in India I have naturally devoted much time to this subject of the manure-supply in its several details.

In Chapter I, when speaking of the exhaustion of soils, I have expressed the opinion that it is far more important to endeavour to increase the fertility of Indian soils, than to discuss whether a process of exhaustion is going on. In the same chapter I have produced evidence which leaves no doubt at all that the Indian soils are uniformly very poor indeed in two all-important particulars, namely, humus and nitrogen; that, in short, whether exhaustion is in process or not, their fertility is at a very low ebb. Seeing, as one may in most parts of India, that but little care is bestowed by the cultivator on his manure heap, that a large proportion of the cattle dung is carefully dried for fuel, the urine wasted, that there is no well-organised system of getting the night-soil and other town refuse on to the land, it becomes at once patent to any one with a knowledge of the agriculture of any advanced country, that in this matter a *most* serious loss is occurring, that indeed no land under the circumstances *could* be in a high state of fertility.

Whatever may be the causes producing the present state of things in relation to the supply of manure to the Indian cultivator, or however great may be the difficulties which stand in the way of their removal, the fact remains that, if the present state of things were altered, a material increase of crops would be the *immediate* result. Nor is it difficult to discern what particular materials must, if carefully applied to the land, form the chief manure-supply. Since by far the greater part of the cultivated area is under food crops, nearly the whole of which is consumed in India by the population and agricultural stock, it follows that the value of the excreta *must* far exceed that of other materials, such as bones, oil-seed cake, etc., which may be added to the list.

61. The questions which I have had an opportunity of enquiring into may be stated as follows:—The quantity of manures, the extent of their present utilisation, their value as grain producers, and their composition. The results of my work on manures has been published in the Agricultural

Ledger No. 8, 1897, and it will be merely necessary for the purposes of this report to explain briefly what has been done.

The following list includes the various manures available to the Indian cultivator :—

(1) Cattle dung and urine and bedding materials.
(2) Night-soil and other city refuse.
(3) Oil-seed refuse.
(4) Bones.
(5) Saltpetre.
(6) River and canal silt.
(7) Green manures.
(8) Influence of leguminous crops.
(9) Sheep folding.

(1) Cattle Manure.

62. The chief points to be considered in relation to Indian cattle manure may be stated as follows :—

(*a*) To what extent is it burnt for fuel, and in what parts of India is it utilised principally for manure ?

(*b*) To what extent is that part of the cattle manure carefully kept for the land, which is not required for fuel ?

(*c*) The value of cattle manure as a means of increasing the food-supply.

(*d*) Its composition.

63. (*a*) In paragraph 123 of Dr. Voelcker's Report, a number of instances are given of places where cattle dung is used largely as fuel, and of others where it is not so used or only to a limited extent, and the general conclusion to which Dr. Voelcker came was that, given a fuel-supply, the cultivator does not burn dung, but is only too glad to use it as manure (*vide* paragraph 124).

When on tour, I also have had opportunity to make observations on this question.

During my tours in the North-Western Provinces (Cawnpore, Farrukhabad and Etawah Districts) and in Oudh (Unao, Lucknow, Bara Banki and Bahraich Districts), I found uniformly that the dung was most carefully collected for making fuel-cakes, and, whenever a large town was within reach, a very large trade in this material existed, the dung cakes being carried as much as 10 miles into the town. In the Deccan I found the circumstances to be practically the same.

Likewise in the Ferozepore, Lahore, Karnal Districts in the Punjab, the dung is put to a similar use. The same must be said to be the case in the Shahabad District in Behar.

On the other hand, in the Dehra Dun, in that part of Muzaffargarh District which I travelled through, and throughout Gujarat, I have found but very little dung burned ; the greater part is put upon the land. It is in one sense more important to study the conditions existing where dung is not burnt as fuel, than where it is burnt. The general consensus of opinion by those few who have really studied Indian agriculture, has been that the cultivator would not burn this dung if he were not obliged to do so. Dr. Voelcker quotes from various reports in support of this. On the other hand, it has been said by others that it is the ryot's ignorance which occasions the practice, and that you may give him as much fuel as you like, but he will still burn his cattle dung ; in other words, that it is his improvidence which is the cause of the present state of things. The same people will also tell you that you cannot improve on the ryot's agricultural practices, that he knows his business best !

To my mind the question is entirely solved by the case of Gujarat. I have mentioned that in Muzaffargarh and Dehra Dun Districts dung is not burnt, but these two districts happen to be quite exceptionally well off for small

wood suitable for fuel, and although there are instances which may properly be quoted showing that, given supply of firewood, the dung will be employed on the land, still it is certainly quite out of the question to expect that such large supplies could be provided in the cultivated tracts generally.

But in the case of Gujarat the circumstances are entirely different. I have myself toured through several districts of this Province, and I found uniformly that for all practical purposes dung is *not* burned, and that the people grow their own firewood. I have not visited every district in this Province, but I have it on the authority of both Mr. Mollison and Mr. Middleton, that the same applies to the Province as a whole. Here one finds indeed a different stamp of agriculture; the fields are hedged; instead of bare useless grazing lands, one has borders of grass round the fields; seed is selected; the manure most carefully collected and placed in pits; and without the aid of any unusual fuel reserves or forests, the people actually grow their own firewood.

With such an example as this before us, I maintain that it is useless to discuss whether the cultivators in other parts are ignorant or not of the value of dung or the uses of firewood. Possibly they are in parts so ignorant; if this is the case, it is simply the outcome of the fact that for long periods they have not known the blessings of firewood and have lost all records of the direct gain of food which the application of dung would secure to the land. For my own part I believe, with Dr. Voelcker, that so soon as a supply of firewood is really at their disposal, they will not be long in putting their manure on the land.

The agriculture of Gujarat is indeed deserving of a much closer study than I have been able to give to it.

64. (*b*) The second matter of practical importance is whether the cultivator takes proper care of that part of his manure-supply which is not required for fuel. Here we must include the dung dropped during the rainy period of the year when it cannot be dried, the urine which is deposited in the stalls all the year round, any bedding materials which may be at hand, and finally, the general sweepings, leaves, etc., of villages which find their way on to the manure heap.

As a general rule, the carelessness with which these materials are thrown aside is a standing proof that, however careful the Indian ryot is of his crops, and although in many things he practises great economy, Dr. Voelcker's criticism is fully justified. Dr. Voelcker says (paragraph 146):—

"Excellent as in many respects his cultivation is, yet in his method of securing to advantage the droppings of his cattle, the ryot is, I am sure, greatly at fault. This is, in fact, one of the comparatively few matters which lie close to hand, in which he can be shown a better way. Perhaps in no respect has the British farmer of recent years advanced so much as in the economy introduced by the proper making of farm-yard manure. The superiority of box-made manure to that of open yards needs no explanation here; the advantage of recovering in the manure the cake which has been fed to beasts is fully admitted, as also the folly of allowing the urine to go to waste. But in India it is quite different; no litter is supplied to the cattle, and not once in a thousand times is any attempt made to save the urine. The solid excrements are picked up, and either made at once into cakes for burning, or else they are thrown on the manure heap, such as it is. The urine sinks into the ground, generally in the hollows worked out by the animal's feet. Now and again a little of the softened earth is scraped away and thrown on the manure heap, but it results in little more than a deeper hollow being made, and serves to expose a fresh surface for the urine to sink into. The value of the urine is, I am sure, not only not fully appreciated, but is actually unknown to a very large number of the cultivators. Did they know its value, they might do something more to save it."

My experience quite coincides with that of Dr. Voelcker. The refuse which is not made into dung-cakes for fuel, is thrown either in some shallow hollow near at hand, or on the road side, or on the banks of the village tank. Rarely have I found any attempt to preserve the urine. One cannot assume any cause for this state of things excepting ignorance.

65. *Bedding Cattle.*—It has been asserted that one cannot use bedding for Indian cattle because they would suffer from attacks of flies and other insects if you did. Dr. Voelcker, in paragraph 147, mentions that the experience at Saidapet is that such a belief is unfounded. So likewise during the last few years at Nagpore and at Cawnpore, the cattle have regularly been kept in sheds with

bedding without any bad effects. At Cawnpore, during the hot weather, the cattle are tied out at night, but this does not prevent the use of bedding materials. Moreover, I have, like Dr. Voelcker, often observed village cattle being kept in sheds. I may mention that at Nagpore, one pair of cattle has been kept for some years, not only in sheds with bedding under them, *but on the box system*, in which 4 feet of manure gradually collects under them, and no evil consequences have resulted.

66. *Bedding Materials.*—In reference to this subject I have explained (*vide* Agricultural Ledger No. 8, 1897) that the conclusion to which I have arrived is that there really is a want of bedding materials.

Whenever I have enquired into the uses to which such things as straws, stalks, leaves, etc., of the crops are put, I have found uniformly that the greater part is usefully employed. Much of these form the main cattle fodder of the country. Another large portion is used for thatching, and the dry leaves of groves are used by the "grain parcher." In the case of dry sugarcane leaves we have an instance of a material which is commonly burned, whereas this material alone, as I have shown in the paper referred to, would provide bedding for no small proportion of the work cattle. But still it cannot be doubted that there is no large supply of bedding materials in many parts, and consequently a "dry earth" system was introduced at Cawnpore last year. The experiment has not been carried out quite as one might have wished, because what one wants to show is that all or nearly all the urine may be readily preserved in this manner, as indeed there is little doubt that it can be, and more time and chemical analyses, than have been devoted to it, would have been desirable. So far, however, the method has proved a great success and is deserving of an extended use.

The experiment consists in this. No bedding, but simply a small quantity of loose dry earth, is scattered on the floor of the cattle stall, and whatever portion is rendered moist by urine is daily removed and dried in the sun. It is then returned to the stall In this manner the earth may become a concentrated manure. So far the nitrogen content of this earth has risen to ·5 per cent. before going to the pits, but I believe that it might be used until it contained as much as 1 per cent. Apparently the whole of the urine can be thus secured, and the cattle have not suffered any inconvenience at all. Eventually the experiment should show what weight of each "urine earth" (if I may so describe the resulting material) is obtained from a part of cattle, and what its value is for crops.

67. (*c*) *The Value of Cattle Manure.*—Cattle manure has been applied for various crops at all the experimental farms, and the tabulated results show that, with an application of about 6 tons per acre, an increased outturn of some 300 to 400 lbs. of wheat has been realised at Cawnpore and Dumraon, and 200 to 300 lbs. at Nagpore. At the latter station the crops have suffered much from attacks of rust, otherwise the average increase would have been higher. In the case of maize at Cawnpore the average increase has been 400 to 500 lbs.

The only doubt which I had in my mind at first was whether 6 tons of cattle manure per acre was a quantity which the cultivator could be supposed to have, on the assumption that he had not to burn any, and that he took due care of the urine.

In Agricultural Ledger No. 8, 1897, I have gone into this question and have produced the evidence which I have collected, as to the weight of dung obtainable from cattle. I have also gone into calculations showing over what area the farm manure may be said to be required, and as an outcome of these deductions, I have shown that it is probable the allowance of 6 tons per acre, as employed at some of the farms for cereals, is not unduly high. Consequently that the experiments really illustrate what the value of the cattle manure is in terms of food-grain.

68. (*d*) *The Composition of Cattle Manure.*—In Agricultural Ledger No. 8, 1897, I have set out the analyses of a number of samples of cattle dung, both from the farms as also from cultivators' cattle.

As will be seen from an inspection of those statements, the samples which I analysed were all much moister than those which Dr. Voelcker analysed of

Indian cattle dung. But if due allowance be made for this difference, it will become evident that the conclusion to which he arrived, namely, that Indian dung is not poorer than English, is fully confirmed. Taking the first lot of analyses, which relate to the dung of village grazing cattle, there was about 75 per cent. of water and about .25 per cent. of nitrogen, or in 25 parts of dry substance there was ·25 of nitrogen, which is equal to 1 part of nitrogen in 100 of dry substance. Again, in the manure from the farms, in which the proportion of moisture has varied from 25 per cent. to 72 per cent., if the proportion of nitrogen in the dry substance be calculated out, it will be seen to be in nearly all cases more than 1 per cent. and in many of them very much more. Indeed they correspond very closely with those which Dr. Voelcker analysed, and are quite as rich in fertilising matters as is the case with English farm-yard manure.

(2) Night-soil and other town refuse.

69. In relation to night-soil, I have endeavoured to collect information of a nature similar to that in respect of cattle manure.

In Agricultural Ledger (Agricultural Series No. 15), I have described the principal methods which are at present utilised for its disposal, and in Agricultural Ledger No. 8, 1897, I have dealt with its value as a manure, and the quantities (in certain specified cases) which are available.

70. The methods employed for its disposal are, *firstly*, that of the people who live in villages and on the outskirts of towns and large villages; *secondly*, the more systematic disposal of it on the large scale by trenching or making it into poudrette.

By means of the first (the customs of the people), a large part undoubtedly finds its way directly on to the land, but still even here one often finds an amount of carelessness which is surprising, and the by-ways become fouled with matters which should be in the fields.

In the case of some towns and jails, the night-soil is taken outside and either trenched directly in fields, or placed in pits with an addition of ashes and other refuse, and in this case the mass is some months later taken out and sold for manure (poudrette).

It is at the Allahabad Grass Farm that I have found the most perfect methods employed. The night-soil is here usually trenched, but instead of the trenches being narrow and deep, about 1 foot by 1 foot, they are really shallow beds, about 14 feet by 5 feet and only 3 inches deep. A cart-load of night-soil is thrown on and the excavated 3 inches of earth put back upon it.

The rate of decomposition of night-soil, when mixed with plenty of earth, is wonderfully rapid in India, and I have several times, when at Allahabad, dug up these "beds" in which the night-soil had been placed only a few days previously, and found no objectionable odour, but one simply like garden leaf mould. In deeper trenches the decomposition takes naturally longer, but at Meerut I found that a fortnight had been ample for the purpose. The advantage of these trenching systems is that practically no nuisance is caused at all.

In the case of the Allahabad shallow system the manure is spread over a very considerable area, but where the trenches are a foot deep, the manure goes on too small an area, at least it has been so in those places which I have inspected. At Meerut, for instance, it worked out to more than *200 tons* per acre per annum, whereas an allowance of one-tenth or one-twentieth of this would have been ample.

An advantage doubtless lies with the poudrette system, in that only a small area of land need be taken up by a Municipality for the disposal of a very large quantity of night-soil. The chief objection to this system is that it undoubtedly causes a great deal of nuisance. If it is made on anything like a large scale, one cannot go within ½ mile of the pits, until, at least, they are closed up. But the resulting product undoubtedly forms a most excellent manure, and its price is constantly rising where it is made.

Its value in this respect may be deduced from experiments at Cawnpore, where it has produced (applied at the rate of about 6 tons per acre for a

number of years) an average increase of from 500 to 1,000 lbs. of maize and from 400 to 600 lbs. of wheat per acre in excess of the unmanured plots; weight for weight it has proved a better manure than cattle dung at this farm. At Poona, too, in the sugarcane experiments, it has produced a heavier crop than its equivalent of cattle dung.

71. *The composition of poudrette* naturally varies a good deal according to how much ashes and other debris are employed in its manufacture; that made at Poona generally contains about 1·0 per cent. of nitrogen and from ¼ to 1½ per cent. of phosphoric acid.

The poudrette at Cawnpore has generally contained from ·4 to ·7 per cent. of nitrogen.

72. The *quantities available* from towns are very considerable, but it is difficult to get exact details. At Meerut the amount removed *daily* from the city (population 73,000) is over 200 maunds (or about 7·5 tons); and about 12 tons is removed from a part of Nagpore, the population of which is 24,000.

The *whole* of the former is put on only about 3 acres annually, and the latter (after being made into poudrette) manures 23 acres annually. I believe that these quantities, especially in the case of Meerut, might readily be applied to many times the area named and still produce the heaviest of crops.

At Allahabad, where it is entirely employed for grass land, the amount applied is also large; in one calculation which I made it worked out to 168 tons per acre, but here they manure only once in 10 years, so that the annual allowance comes to only some 17 tons. The weight of green grass obtained has varied from 10 to 30 tons per acre per annum, which is equal to 3 to 10 tons of hay.

I believe that one of the chief difficulties which at present exists in relation to night-soil is the cost and trouble of carriage. Only certain castes will do the work, and these are actually too few to take the material any great distance from a city. But I am convinced that, if this difficulty could be overcome and the night-soil taken further afield, its market value would largely increase and a much larger area become fertilised.

73. *Urine.*—I have mentioned that the night-soil of jails is utilised for manure. In some cases, apparently, the jail garden is not sufficiently large to take all the manure produced. For instance, the Superintendent of the Presidency Jail, Calcutta, asked me what he was to do with his garden; he had formerly been able to raise large crops, but latterly the land had not been so productive, and he had concluded that his manure supply was deficient. There was naturally a large import of food stuffs into the jail, and the whole of the night-soil and urine produced was applied to the garden which had an area of some 5 acres. On going into the figures relating to this case I found that there was a very large *annual* increase of manure, containing not less than 10 times as much plant food as was required by the crops. This had been going on for some years, and I had no doubt at all that the supply of manure had been so great, that what the soil really required was thorough exposure to the air.

Again at the Meerut jail garden, they find the night-soil alone sufficient for the crops, and have thrown the urine into pits. This is a matter which Mr. Wyer, the Collector, took up. Urine is a difficult material to carry any distance since iron carts are necessary. Mr. Wyer therefore tried the experiment of pouring it, in small quantities at a time, on earth, ashes, etc., and found that by allowing the material to dry between each addition, a valuable *dry* material could be produced, which could be carried in an ordinary cart. It does not follow of course that all jails have too large a supply of manure for their gardens, since it naturally depends on the area cultivated, but the instances noted are of interest.

74. *Sweepings.*—In addition to the night-soil, there is of course a vast amount of rubbish and sweepings from the streets, and this also, under improved conservancy arrangements, is now being sent out of the cities by carts.

Samples of this material from Poona and Dumraon have contained about ·3 or ·4 per cent. nitrogen, so that, although it is not nearly so concentrated

a manure as night-soil, it is nevertheless a valuable manure, and has been largely used on the land. At Poona it is employed for sugarcane, at Allahabad for grass land. It has no offensive odour. Unfortunately it is also largely employed for brick-kilns, and very large quantities, in some places most of it, are used for this purpose and thus lost to agriculture.

75. *Sullage Water.*—Another "refuse material" obtainable from the cities is the drainage or *Gunda nalla* water. This stream of evil smelling water is generally run into the nearest river.

I have only met with one city where an attempt has been made to utilise it on the land, and that is Meerut. Mr. Wyer, the Collector, utilised his small farm for the purpose of illustrating its value to the ryots. The cultivators held the belief that it would injure their crops if run on to the land, but Mr. Wyer showed them that this was merely a fallacy. It proved *most* beneficial at the farm. Two irrigations with it doubled the outturn of cotton, maize, juar and oats over that obtained with well water. Nor were the people slow to perceive its value, and at once rigged up *dhenklis* to raise it on to their fields.

76. From the foregoing it will be evident that there is a very large supply of manure in all the large villages and towns, and that, if it could be sent out rather further than is at present the case, and spread over a larger area, a very great benefit must accrue to the cultivators. Moreover, instead of conservancy costing towns thousands of rupees per annum, I feel certain that, as at Meerut, the cost might be wholly recovered.

Conservancy is apparently looked upon as a nuisance; it should be considered rather as a source of *profit*.

(3) Oil-seed refuse.

77. The value of oil-seed refuse, either as a cattle food or as a manure, is recognised generally by the Indian cultivator. Sometimes one finds that even here caste prejudice stands in the way, as for example, in the Lucknow District, where the people will not employ castor cake for *pán* (*piper betel*). But I have not found anything that one could designate wastefulness in relation to these materials. The edible sorts of oil-seed cake, such as rape, safflower, til, and earthnut, are fed to cattle; also cotton seed (unpressed), and some of the non-edible sorts, particularly castor seed cake, are used as manure.

In the sugarcane experiments at Poona some of the *edible* cakes have been included in the list of manures. Mr. Mollison, while quite admitting that the proper use of the edible sorts is primarily food and not manure, has pointed out (*vide* Poona Farm Report, 1895, page 30) that that portion which is fed to cattle becomes lost to the soil, the dung is burned and the urine lost. He further observes that the current market prices of certain non-edible cakes, such as castor, which are regularly employed as manure, are higher than some of the best feeding cakes, and that consequently, if the edible cakes have a manure value equal to the non-edible ones, it would pay to use them, and accordingly several of the latter are being experimented upon.

In the Agricultural Ledger (No. 8, 1897) already referred to, I have detailed what information exists as to the manurial value of these oil-seed cakes. I have also gone into the question of their export. In paragraph 127 of his Report, Dr. Voelcker pointed out the advantage which would accrue if these seeds could be more largely pressed in India, and the oil *only* exported in place of the whole seed. The result of the comparison which I drew up in the paper alluded to, was to show that nearly two-thirds of the linseed produced is exported, of the rape and mustard about one-sixth, of the sesamum about two-thirds, of the earth-nut about one-third, but of the cotton seed less than half a per cent. of that produced is exported. Of the total of these, less than one-third is exported. Statistics do not exist as to the amount of outturn and exports of the other oil-seeds, but it is certain that the *proportions* exported of these are smaller than is the case with those above-named. Of course the whole question of this export depends on the demand respectively in India and in Europe. The European agriculturist buys the edible cakes primarily for cattle fodder, and secondly, he secures the manure produced for raising crops. The Indian ryot uses the edible ones for cattle food, but loses the manure, and whilst this state of things exists, it is not surprising that the

European farmer can afford to offer such a price as will withdraw these valuable materials from India.

(4) Bones.

78. Dr. Voelcker has gone into the question of the export of bones from India, and in the Agricultural Ledger referred to, I have detailed such evidence as has been obtained at the farms of their value as manure for Indian crops. In the case of only one farm, namely, Burdwan, have they proved to be of any benefit at all; at this farm crushed bones have proved a valuable manure for rice, and, in a less pronounced degree, for jute also. But at Dumraon, Cawnpore, Nagpore and Poona they have been of no more value than, if as valuable as, any other manure which supplied an amount of nitrogen equal to that in the bones. Nor, as I have pointed out in paragraph 50 of this report, can their export be considered as causing any material drain on the resources of the soil.

(5) Saltpetre.

79. There is little need to discuss the value as manure of saltpetre; in the first place, its qualifications in this respect are well known, and indirectly the cultivators in India also recognise it. For instance, the earth of old dwellings and other scrapings of villages are put on the land as manure. Again, the manurial value of certain well waters is understood, and in one case, namely, the Charotar in Gujarat, which I have described in Agricultural Ledger (Medical and Chemical Series No. 2), the well waters contain very large quantities of saltpetre, and the value of the wells is consequently very considerable. At the experimental farms, too, saltpetre has been found to act in the same rapid manner as it does in England. But the market price of the dry, and more or less pure, saltpetre is much too high, to admit of its being employed as a manure. The nitrogen in it costs about three times as much as that in poudrette, and there is a still greater difference between it and cattle dung. Indeed, on this account it cannot strictly be considered as within the ryot's reach.

(6) River, Canal and Tank Silt.

80. One constant supply of fertilising material, which though not "concentrated" like the so-called manures, undoubtedly plays an important part in relation to Indian agriculture, is the silt which is brought by rivers and canals on to the land.

In some parts, such as Eastern Bengal, where the rivers flood the surrounding country, the advantages indicated apply to very large areas.

Then, too, the canals, which at present irrigate more than ten million acres, also bring no small quantity of silt on to that area.

Thirdly, in the case of tanks which are supplied by flood waters from higher ground, accumulations of silt are formed, which are periodically dug out and spread upon the land for manure.

All this means, when *considered in the aggregate*, a constant and very material source of "manure," and since it is almost entirely brought from uncultivated on to cultivated land, it fills the place of an *imported* fertiliser. It is difficult, if not impossible, to form a correct idea of the real value of all this silt.

In 1893 Sir Edward Buck requested me to experiment on the value of canal silt. The field experiments which Sir Edward Buck suggested proved difficult of execution, but the enquiry was carried on in the case of one canal, by measuring the amount of water which was applied to certain areas, and weighing and analysing the silt. The results of these experiments have been published in Agricultural Ledger (Agricultural Series No. 20), and they show that the silt, in the case of the Upper Eastern Jumna Canal at least, is sufficient to supply the requirements of a rice-crop, but not nearly sufficient for a wheat crop. The silt for the monsoon period contributed 32 lbs. of nitrogen and 41 lbs. of phosphoric acid per acre. During the cold weather, when the water is nearly clear, the amount supplied was in 1895-96 half a pound of nitrogen and about 1 lb. of phosphoric acid per acre.

It is indeed probable that rice lands generally owe their fertility to these silt deposits. Rice lands commonly consist of terraces, and whatever be the

source of the irrigation water, it is always muddy during the monsoon, and a part of its silt undoubtedly becomes deposited on the fields. It is, I believe, for this reason that these fields can do better without manure than most other classes of lands in India.

But of course all silt is not valuable. Everything naturally depends on its nature. For instance, in the case of the *chos* lands of the Hoshiarpur District, Punjab, large quantities of *sandy* silt are brought on to the cultivated lands, and actually cause very serious damage.

(7) Green manures.

81. The practice of growing a crop and ploughing it into the land whilst still immature to serve as a fertiliser for a succeeding crop, whilst adopted in some parts of India, is not general. The value of the process has formed the subject of experiment at Cawnpore and Nagpore for some years, and the results of these experiments have been discussed in Agricultural Ledger (Agricultural Series No. 7), in which it was shown that an increase of several hundred pounds of wheat per acre had been realised by growing and ploughing in a crop of indigo and san hemp during the preceding monsoon. The rate of increase depends much on the circumstances of the year, according to whether the green crop has grown well, and whether there is enough moisture, after ploughing in, to thoroughly decompose the material. Sometimes it has been found at Cawnpore that harm has resulted from the fact that the green crop never rotted down properly, and in some years these *green manured* plots have produced less than the unmanured plot. But in the majority of years an actual increase of outturn has been realised.

In 1893 I recommended some alterations in the experiment at Cawnpore, and the number of green manures now ploughed in has been increased to five, *kurti*, *urd* and *rape* having been added to the list.

(8) Influence of leguminous crops.

82. In Dr. Voelcker's report the value of the leguminosæ in enriching the soil is referred to in the chapter on soils (paragraph 60). In my paper on Indian manures (*vide* Agricultural Ledger No. 8, 1897), I have included a reference to this subject, classing the general cultivation of *leguminosæ* under the head of manures. At the Cawnpore Farm the influence of a previously grown leguminous crop has been tested for a following wheat crop over a number of years. Previous to 1893 indigo and san hemp and lucerne were grown. They were harvested and wheat then followed. Indigo has generally occasioned an increased yield of several hundred pounds per acre; the corresponding value of hemp has not been uniformly demonstrated, and a decreased outturn of wheat has on several occasions resulted, and the case has been much the same with lucerne.

The number of leguminous crops, grown thus in alternation with wheat, were increased in 1894, *arhar*, *urd* and *gram* having been added to the list.

Again, as explained in paragraph 156 of this report, another section has been added to these experiments at Cawnpore, on the effects of a leguminous crop, and some crops of this natural order will be grown *with* certain other crops, to endeavour to test whether the leguminosæ have any *direct* influence on plants of other natural orders. There are certain difficulties of a practical nature to which I have referred in paragraph 156, in experimenting on this question *in the field*, but it is certain that the constant cultivation of leguminosæ in rotation, or *with* plants of other natural orders, as is so commonly done, must be playing a most important part in the economy of Indian Agriculture.

(9) Sheep folding.

83. Dr. Voelcker has pointed out in paragraph 126 that the practice of folding sheep on the land is common in some parts, and I have also found the same to be the case. In fact, although it is difficult to form an exact opinion on the subject, I believe that the value of this method of fertilising the land is far more generally recognised by the cultivators than one might have expected, and where herds of sheep are kept at all, this custom provides a no-inconsiderable amount of manure.

CHAPTER IV.

Wood Fuel.

84. Dr. Voelcker devoted Chapter VIII of his report to a discussion of the question of a better supply of wood fuel for agricultural purposes so as to set the cattle manure at liberty for its more legitimate purpose, and he strongly urged that Government should take an extended action to supply this deficiency. Although I very fully endorse all that Dr. Voelcker has said in that report, I should not be justified in leaving unmentioned one point in relation to this subject, which I should have found a difficulty, had I been called upon to try to carry out the *spirit* of Dr. Voelcker's suggestions to their practical issue.

So far as opening up forests of one description or another to grazing, etc., is concerned, it is one which can only be dealt with by the Forest Department, and doubtless these will be opened up for extended use by cultivators as far as practicable.

I wish to refer for a moment rather to the smaller *village reserves*, which I take it Dr. Voelcker considered feasible, as well as desirable. In considering the subject of a supply of firewood to cultivators, the first question which must, on the face of it, be answered, is, " how far will a cultivator be willing to carry firewood from its source of supply ?"

This is a most important question, because it will be clear that it is useless to say, " there are inexhaustible supplies of small wood in the Himalayas or the Central Provinces, forests which the ryot may take," if he cannot, on account of the distances, afford to go for it ! I mention this, because it is the answer which a Forest Officer actually gave me, when I broached the subject of firewood with him.

From enquiries which I have made I am certain that cultivators cannot afford to carry firewood more than 10 miles, and I doubt if he can go as far as this. But even assuming this to be a practicable distance, it must be clear that any system of village fuel reserves would mean the creation of an *enormous* number of small plantations. Now the practical difficulty lies in this: how could such a system of fuel reserves be managed ? If it were the case that the management could be left to the people, such a proposal might perhaps be carried into effect. But at present one cannot suggest that the people are capable of managing them themselves. The individual and conflicting interests would alone form one insurmountable obstacle, and their present ignorance would form a second. A proof that I am not overstating the case lies in the condition of the large grazing areas. Owing to absolute neglect, these are not only producing very much less grass than they might do, but they are everywhere being cut up by surface wash into ravines. It must be admitted that, if the people will not protect their grazing areas (which are in many parts the common property of a village), they certainly would not work a fuel reserve properly.

85. But if the management of a village fuel reserve cannot be left to the people, then the only other agency would be a Government Department, and with this would be included the " chaprassie " or other subordinate official; an item which, in my opinion, would alone be sufficient to make a village fuel reserve of no benefit at all. It is herein that the practical difficulty lies, for constant supervision of a large number of small fuel reserves by Europeans is out of the question.

So far as villages are concerned, I cannot help thinking that what should be aimed at is to emulate the example of Gujarat, where, as I have said in Chapter III, the people grow fuel along the field borders and do not depend so much on actual plantations.

Of course, such a suggestion can only be carried into practical effect when, by means of an extended system of agricultural education, such advanced practices as one meets with in Gujarat can be brought to the knowledge of the people.

86. Regarding fuel reserves, however, it has always seemed to me that they *might* be practicable *for towns*. The firewood grown at Changa Manga is carried not only to Lahore but even to Amritsar, and although large quantities of canal water are used at this reserve, a net profit of 8 annas per acre is realised. It seems to me to be a crying shame that the large towns, peopled by those who are immensely better off than the cultivator, should not only make no proper endeavour to hand back the manure which has been withdrawn from the surrounding villages (in the form of food stuffs), but that, in addition, they should depend to a very large extent on the cattle dung for a supply of fuel.

I have mentioned that, I believe, the cost of conservancy might be entirely recovered, if the manure were carried out to the people in a business-like manner, and there is little doubt that fuel could be produced for towns at *no* actual net cost at all. It might even become a source of revenue.

CHAPTER V.

IMPLEMENTS.

87. In Chapter XII of his report Dr. Voelcker explains briefly in what directions attempts at improvement of agricultural implements had been made in India, and whilst admitting that it is quite feasible to assist the ryot in these matters, he at the same time points out how necessary it is that whatever attempts be made in the future, should be undertaken with the assistance of thoroughly qualified persons, and that "where any improvement is possible, it will come mainly from without and not from within, that is, by the application of Western Science to native ways and requirements." In June 1892 the Government of India issued a Circular No. 23—103, requesting the Local Governments to obtain, through the Agricultural Departments, descriptive lists of native agricultural implements, the object being to collect information for the study of native agricultural implements.

The result of this reference was the compilation of very exhaustive lists of various implements, including not only the larger ones employed in actual tillage of the soil, but also such small ones as weeding tools, household utensils and implements such as those required by fishermen.

In September 1895 these lists, together with the illustrations, drawings or photographs, which had thus been collected from the various Provinces, were sent to me with instructions that I should take the opportunity of discussing the subject when on tour with Farm Superintendents and others who might take an interest in the matter, with the object of ascertaining whether any implement found useful in one part of India could be recommended for trial in other parts.

During the ensuing cold weather I took the opportunity of discussing this subject of implements with the officers of the several Agricultural Departments of the Local Governments, and went into the matter as thoroughly as circumstances would admit.

I also put together, as soon as possible, a note embodying the results of such actual measurements of the work done by implements, both indigenous and imported, as had appeared in reports in my possession, and this note was circulated to Directors of Agricultural Departments and others, who I thought could render assistance.

I may mention in the first place that it was generally agreed that for all practical purposes many of the implements mentioned in the lists might advantageously be omitted for the time being from consideration. Such, for example, were household utensils, sieves, nets, sickles, and the like.

The implements which were more thoroughly considered were those larger ones which are employed for tillage operations, irrigation, and harvesting.

88. As an outcome of this reference, I received two interesting notes on the subject, which were referred to in detail in my Annual Report for 1895-96.

Mr. Wyer, then Collector of Meerut District, gave his experience with the sugarcane mill, and expressed the opinion that exhibition of implements at shows would be a most valuable means of introducing them to the cultivator, and further that "nothing is more certain than that the extended use of machinery must come before long."

Mr. Benson, Deputy Director of Agriculture, Madras, pointed out that in the case of some implements, such as sugar mills, it is easy to demonstrate such advantages as they may possess, whilst in the case of others, such as ploughs and seed-drills, such advantages are more remote and difficult to appreciate.

The Director of Land Records and Agriculture, Punjab, wrote expressing the opinion that, if suitable seed-drills and threshing machines could be obtained, they would prove an advantage in the Punjab.

The Director of Land Records and Agriculture, Bengal, considered that attention should be principally directed to experiments with seed-drills and water-lifts in addition to ploughs which had been the subject of experiment for some years.

The Director of Land Records and Agriculture, North-Western Provinces and Oudh, considered that there was room for more useful work in relation to water-lifts than in the case of other implements. The work done by some of these appliances had been ascertained by Colonel Clibborn, but in the case of others exact information was wanting, and Mr. Baillie applied to his Government for permission to have a number of measurements made of the work done by these latter.

With regard to the chain pump, which has been made for some years at the Cawnpore workshop and sold, Mr. Baillie expressed the opinion that with the advice of a mechanical engineer, this appliance might possibly be improved upon, and asked Government to allow the Department to have the advice of such an expert.

The Commissioner of Settlements and Agriculture, Central Provinces, offered to have a number of measurements made of the work done by water-lifts in the Provinces. Mr. Joshi, Superintendent of the Experimental Farm, had altered the indigenous seed-drill in several respects, with the result that its efficiency was increased and labour saved.

89. The principal implements may be suitably referred to individually.

Ploughs.—The subject of the application of an iron plough of one description or another to Indian agriculture has been discussed now for many years. Generally, it appears to have been asserted that the Indian cultivator merely scratches the surface of his field, and that deep ploughing is a thing rarely met with. To my mind no greater mistake could be made than this.

It is necessary, however, when speaking of this operation (ploughing), to define what is therein included. In England the land is first opened up by a plough and the seed-bed is then prepared by other implements. In India, although there is a great variety of implements employed in different parts, the seed-bed is more usually prepared by means of two implements, the one which English writers have generally named a "plough" and which more nearly corresponds in its action to the English "cultivator" (though only possessed of a single tine) and a log of wood ("patela") with which the clods of earth are broken down. The land is first broken up by the plough, then the wooden log is drawn over the field, then the "plough" is again applied and the alternate process of ploughing and levelling repeated until the desired tilth has been obtained.

It is the depth of this tilth which is the important item. It matters little, when discussing how deeply the land is "ploughed," whether the seed-bed be prepared in one or two or in twenty operations. If the final result be a seed-bed of 6 inches or more deep, it is manifestly a mistake to say that the land is only ploughed a couple of inches deep, although this may be, and frequently is, the case if only the first ploughing be considered.

It is true that much, perhaps most, land is not cultivated to a greater depth than 4 inches or 5 inches, but from the frequent observations which I have made, I believe that the latter figure would not incorrectly represent the truth. In the first place, rice occupies one-third of the cultivated area, and most of the land which I have seen prepared for rice was cultivated deeper than 5 inches.

Then again in the black cotton-soil (*regur*), although it is frequently not customary to plough this land every year, but only to scrape its surface to a depth of some 3 inches with the "bakhar," the ploughs which are used every second or third year are uniformly large ones working from 8 to 12 inches deep. Dr. Voelcker mentions one of these heavy wooden ploughs, that common to Khandesh, on page 218.

These areas, taken together, represent a very large proportion of the total cultivated land of India. On the other hand, it is certain that there are

considerable tracts which are not cultivated deeply. I am not altogether able to give a definite reason for minor differences on a point like this, but I may say that, so far as I have been able to form an opinion, it would seem that some castes of good cultivators employ a plough which works much more deeply than do other castes. Mr. Francis, for example, pointed out to me the difference between the shape of the plough used by the *jats* and that used by other cultivators in the Ferozepore District, and similar differences occur in some districts of the North-Western Provinces and Oudh.

Nevertheless I am convinced that the seed-bed is usually a great deal deeper than the couple of inches with which it is popularly described.

90. Again, an objection which Dr. Voelcker raised to deep ploughing was the loss of moisture which would ensue to the surface soil (presumably in the dry weather). Dr. Voelcker does not suggest this as a quite universal objection, for at the end of paragraph 281 he says that deep ploughing for sugarcane land at the first would not be objectionable, for the loss of moisture in the surface soil becomes of little consequence since this crop is usually irrigated. But then surely the same remark would apply equally to all irrigated land! But there is also another fact which is deserving of notice. In some parts, such as the Ceded districts of Madras, land is deliberately opened up to a depth of 8 or 10 inches *at the commencement of the hot weather* and allowed to lie exposed until the advent of the monsoon, and I have seen the same thing done in the North-Western Provinces. Thus, certainly in some extensive tracts, the land is purposely exposed to the sun throughout the hot weather. One cannot say offhand that the practice is wrong. But if it is right, then it cannot be urged as a *general* objection to deep ploughing, that the surface soil thereby loses its moisture! These remarks are not made in support of the introduction of iron ploughs; their purpose is merely to endeavour to get rid of what I believe to be fallacies. Then, again, it must be borne in mind that there is so much difference between the soils of various parts of India that it is pretty certain that what is suitable in one place, will not be so in another.

91. Another point which has been brought into this discussion of the merits and defects of the native plough, is the question of time. It has been urged by some that the matter of time is of great importance in relation to this operation. It has been pointed out, and I believe with truth, that it is very commonly the case that the whole operation of preparing the seed-bed and getting in the seed *has* to be performed within quite a limited time. This is especially the case with kharif crops. Whether the land be broken up at the commencement of the hot weather (as already referred to) or not, further work in this direction is practically stopped (except with the aid of artificial irrigation) *until the advent of the monsoon*, on account of the hardness of the land. Is it then a matter of indifference at such a time whether a cultivator spends one week or three on the preparation of his land before he can sow?

92. In the note on implements which was circulated to the Directors of Agriculture, I set out briefly what had been done in the direction of trying to improve the indigenous plough. Generally what has been aimed at has been the production of an *iron* plough, more or less on the European pattern, with a mould board, and of a very varying size, which it has been hoped would suit the cultivator better than his wooden one. In Madras and the Central Provinces large-sized iron ploughs have been recommended to the ryot; in Bengal and the North-Western Provinces small ones have been specially made up for him.

The outcome of this is that up to the present iron ploughs have only been really adopted by the cultivator in one part. In the Ceded districts of Madras Presidency a large iron plough of European pattern has been somewhat extensively adopted by the people in place of their *large wooden* one, and a regular trade in this style of implement has sprung up. Details regarding this innovation have been given by Mr. Subba Rao in Bulletin No. 33 of the Madras Agricultural Department.

A number of iron ploughs (of a small type) are annually sold from the Cawnpore Farm, but so far they do not seem to have been really taken up by the people seriously. Syed Mohamed Hadi, Assistant Director of Agriculture, North-Western Provinces and Oudh, recently told me that the cultivators of

Bulandshahr District seemed to be really adopting them, but so far as I know, no great demand for them has yet occurred.

At several of the experimental farms the iron plough has been tested against the indigenous wooden one through a series of years. The general outcome of the experiments has been to show that the crop obtained has been quite as good, or somewhat better, after ploughing with an iron plough. But, in addition, it has been found that the work has been done in half the time and with about half the labour that was required by the wooden implement.

Since it would seem that it is only in the Ceded districts that the people have really considered the iron plough to be better than their own, it will be of interest to notice the reasons which Mr Subba Rao (l.c.) advances in explanation of the change :—

"All ryots who have tried the iron ploughs are of opinion that with them a given area can be ploughed much sooner than with the *peddamadaka*. For instance, the first four ploughs referred to in the statement given above can each plough about two-thirds of an acre of black cotton soil on the average in a day, while the *peddamadaka* can hardly plough half an acre a day; an iron plough in one operation reduces the soil to as good tilth as a ploughing and a cross ploughing with the *peddamadaka*. Above all, cross ploughing is not generally necessary for land tilled with an iron plough, and is very easily done if necessary at all. Similarly, the small iron ploughs are twice as speedy in ploughing a given area as the big country ploughs drawn by two or three pairs of cattle. The bigger iron ploughs exterminate very effectively the weed called *kundara nattu* (Ischaemum pilosum), though not so effectively the *hariali* grass. The cost of cleaning foul land by digging the soil with a pick (Tel guddali) is R15 per acre and sometimes even R20, whereas the cost of cleaning it with an iron plough is hardly more than one-fifth as much. Experienced ryots say that the productiveness of the land is not materially increased by deep tillage with iron ploughs in the first year after the ploughing, but that it is in subsequent years. The ryots who have tried iron ploughs are also unanimously of opinion that, while for the *peddamadaka* the first two pairs of bullocks at least need to be very strong and such as are worth about R100 to R150 a pair, all the five or six pairs yoked to an iron plough may be of the same quality and only such as are worth R50 to R70 a pair. In the Bellary District, one driver, often only a boy, is found sufficient for each two pairs of cattle yoked to these ploughs."

It will be seen that the advantages said to be realised are time, economy of labour, better work, and that less valuable cattle are required. The difficulty of repairs is apparently being overcome, for Mr. Subba Rao mentions that the native smiths of several villages are now able to do this work.

93. *Seed-drills.*—Another implement which I brought up for discussion with Directors of Agriculture was the seed drill. Curiously, crops are usually sown by means of a seed-drill in the Deccan, Central Provinces, and upper part of Madras. Generally in other parts of India this implement is not known. In paragraph 282 Dr. Voelcker refers to the efficiency of the native drill, and Mr. Benson, in a note which he forwarded to me in 1896 on implements, likewise points to the advantages which it possesses.

As an outcome of the discussions which I had with Directors of Agriculture, specimens of this bamboo-drill were sent to the Punjab and North-Western Provinces, but of course it is too early to say whether it will prove of any value. I may observe, however, that it can only be efficiently employed by a practised hand, and unless this item be provided, the crops will be sown worse than by broad casting. Mr. Subbiah, Principal of the Cawnpore Agricultural School, sowed crops with one last year, and the results, though not failures, showed him how necessary it was that the workman should be proficient in its use.

I believe that in a case of this sort, where it is proposed to transfer an implement or method from one part to another, it will be *necessary* to bring a man or men also from the district where the implement or method is indigenous to demonstrate its working.

In another case, namely, the tying up of sugarcane as practised in Bengal, it has been found necessary to bring a man who knew all the details of the process to the farms where it was desired to introduce it. At Dumraon this was done and the method proved successful; at Cawnpore reliance was placed on a written description and the result was a partial failure.

I may mention, too, in reference to the seed-drill that Mr. Joshi, Superintendent of the Experimental Farm at Nagpore, has introduced iron tubes in

place of the bamboo ones. The latter frequently become choked at the *nodes*, where there is a constriction of the tube, and the seed-supply becomes interrupted, and the iron tubes have been inserted to overcome this difficulty.

94. *Bullock Hoes.*—In those Provinces in which seed-drills are employed, weeding is done with a hoe drawn by bullocks. The employment of such an implement means naturally a very great saving of labour, but it can only be used for crops which are sown in regular lines, as is the case when the drill is used.

This implement has also been brought to the Punjab and North-Western Provinces for trial in conjunction with the drill.

95. *Threshing Machines and Winnowers.*—These have been used regularly at some of the farms, more especially Nagpore and Cawnpore, for many years, and it is clear that the work is done far more rapidly by their use than by native methods, but I have not recommended them for demonstration to the cultivators. In wet years there is no doubt that corn is damaged by being exposed to the rain, which loss machinery might avoid, but such machines are somewhat expensive.

96 *Water-lifts.*—Among agricultural implements there is probably none in which so much useful work might be done as in the direction of improving the appliances used by the cultivator for raising water. Determinations of the amount of water raised by the various appliances used by the cultivator have been made in most parts of India, and when preparing the note on implements, I collected such results of these measurements as I had in my office, and reduced them, as far as possible, to one standard.

Some of these measurements have been done with considerable accuracy, as for example, those by Colonel Clibborn for the North-Western Provinces, and by Mr. Campbell for the Bombay Presidency. Others are less accurate, and for some implements, such as the swing basket and the wooden shoot, there are no measurements which can be considered reliable.

Consequently, I urged the desirability of having measurements of the efficiency of such water-lifts made, so that they could be compared with the others.

It must be recollected that raising water is a purely mechanical operation, and that, whilst the motive force, cattle or men, varies in quality, still it is a perfectly simple matter to find out how much of the power exerted is wasted and how much usefully employed in raising water.

It is also clear that a correct knowledge of the *efficiency* of these appliances is necessary, so that, if any improved lift be tested, a correct opinion may be at once formed as to its merits in relation to the ryots' implements. In this view I was met with general concurrence on the part of Directors.

In the Central Provinces the Commissioner of Settlements and Agriculture has had made, during the past year, a number of measurements of the work done by water-lifts in several districts. In the North-Western Provinces the Director similarly recommended that measurements for those lifts which Colonel Clibborn had not included, should be made, but the famine has, I understand, prevented the carrying out of his proposals.

The Directors of Madras and Bengal Agricultural Departments also concurred in the view that measurements of the indigenous appliances should be made.

97. Regarding improved lifts, several have been introduced, and in support of the possibility of improving native implements of this nature, I may here point out that, whilst with the leather bucket or the Persian wheel as employed by the cultivator, the average work done is less than two foot-tons per head of cattle per minute, two lifts (both quite within the reach of the ryot) were exhibited at Madras in 1895, one of which had an efficiency of over 4 tons and the other over 3 tons per head per minute. Thus it is certain that it *is* possible to help the people in this direction.

At Cawnpore a chain pump (chiefly for short lifts) has been made for some years, and some have been sold. That it is a success from the mechanical point

of view is clear not only from the trial measurements, but also from the fact that when irrigation is done at the farm by contract, the work-people prefer to use this pump rather than the swing basket. This pump has been bought to a limited extent, but it has not been taken up generally. Gear has been applied to it for bullock power, and Mr. Baillie, lately Director of Land Records and Agriculture, has urged that this implement should be thoroughly examined by a mechanical engineer. It is unnecessary to go into further details of the work done by different water-lifts. As explained, it was generally agreed by Directors of Agriculture that the more accurate estimation of the work done by some of the native appliances was desirable.

98. In conclusion, I may very briefly express the opinion which I have formed on the subject of implements. I look upon iron ploughs more in the light of time-saving machines than anything else, and so far as I have been able to judge, the matter of time in the preparation of the seed-bed for many crops is of more importance than has been frequently supposed.

Regarding the seed-drill, I am unable to give any reason why its use should be confined to a certain part of India, whilst it is unknown in others. I am firmly convinced, however, that for many crops it would prove of great advantage in those parts of India where it is unknown.

Regarding threshing and winnowing machines, it is clear that they are essentially time-saving appliances, and whilst I have seen grain rotting under the influence of rain, it seems to be unusual for such circumstances to transpire. Generally it has seemed to me unlikely that the people will require this class of machinery at any early date.

Lastly, with regard to water-lifts, judging by the registered efficiency of those which have been examined, I believe there *is* room for improving some of them. Indeed, I am of opinion that there is much more room for useful work in relation to this, than in the case of any of the other chief agricultural implements. But it is work which will have to be done by *mechanical engineers* and in order that those who may wish to take up the matter (for it may be anticipated that actual improvements will be brought out more especially by private firms in the same way as has been the case with the sugarcane mill) may know whether their novelty is a real improvement or not, it is most desirable that careful measurements of existing native appliances should be provided by the Agricultural Departments. Some of this work has already been done, but there is much that remains undone, chiefly the relative efficiency of the short lifts worked by manual labour.

CHAPTER VI.

Hay and Fodder Crops.

99. To the subject of Indian fodders, regarding the composition of which we know practically nothing, I have been able to devote but little time. My investigations into the subject have been limited to the analysis of a few samples of hay, straws and roots, and two *Sorghums*, namely, *Sorghums halipense* and *vulgare*.

100. *Hay.*—One of the first fodders to which my attention was directed on coming to India was the grass produced on the Government Usar "Reserves" at Cawnpore and Aligarh. I found that, although one of the results of enclosure from grazing had been the spread of grasses on these lands, no revenue had been obtained by the sale of grass or hay, and indeed the general opinion was held that the hay produced was of little value as fodder.

The hay at these usar reserves had been made from grass which had become dead ripe, and consequently even the best of it was only the over-ripe stems of the grasses, the seed having been lost, and as a consequence the woody fibre had become higher and the albuminoids lower than would have been the case had the grass been harvested at the flowering stage. At the same time, the hay that was made, was by no means of bad quality, and it was possessed of a very fair aroma. I have had several opportunities of examining hay made from usar grass, and the chemical composition is set out in statement No. 17.

Statement No. 17.

Composition of Indian Hay.

	Gursikran Hay 199 / 93	Gursikran Hay 396 / 94	Usar Hay 122 / 97	Commissariat Hay 144 / 73	Plumed grass Juhi, Eragrostis nutans 17-a / 95	Kaira District Hay 295 / 95	Nagpore Hay. Grass cut ripe.	Nagpore Hay. Grass cut green.	English Hay.
Water	4·75	13·83	6·87	11·07	10·07	8·72	9·81	9·23	17·90
True Albuminoids	3·06	3·56	5·60	2·69	4·45	2·45	1·54	2·46	7·25
Carbohydrates	50·87	48·16	48·99	45·40	50·80	45·87	39·39	44·16	46·13
Woody Fibre	32·04	25·42	30·08	32·07	29·76	34·48	34·58	31·75	22·62
Ash	9·28	9·03	8·46	8·77	4·92	8·48	14·68	12·40	6·10
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen (total)	·49	·57	1·05	·47	·86	·45	·261	·411	...
Albuminoid Nitrogen	...	...	·89	...	·71	·39	·247	·394	...
Sand	6·39	5·89	5·31	6·72	2·55	7·33	12·01	10·66	...

The first two analyses are of hay made from such dead ripe grass at Gursikran, Aligarh. The third was also made from usar grass, but cut during the monsoon, and it will be seen how much higher is the proportion of albuminoids. The fourth is of hay made at Bareilly.

The fifth is the analysis of a grass, *Eragrostis nutans*, which I found in flower at the end of August at the Juhi Usar Reserve. Here again the proportion of albuminoids is much higher than in the hay which had been cut dead ripe, and it is an illustration of the advantage which would ensue from cutting grass at the flowering stage. The sixth sample is one which I obtained in the Kaira District, Gujarat, Bombay, and represents the average quality of the hay which is sent from that district to Bombay in large quantities. In this case also the grass was cut dead ripe and the albuminoids are consequently low. The seventh and eighth are analyses of hay from Nagpore, the

one of which was cut dead ripe, the other of grass cut green, and again here the advantage of early cutting is demonstrated in the large proportion of albuminoids and soluble carbohydrates in the younger grass.

Finally, in the last column of the statement, I add the analysis of a sample of good English hay. None of the Indian samples approach it in quality, but this cannot be expected, since the grass lands at home are regularly manured, whilst those in India are purely waste lands and have nothing done for them.

One thing, however, is made evident from these analyses, namely, that the hay obtained from the usar land is not the useless fodder which it has been termed, for it is quite as good as that made in Gujarat and which is carried by rail all the way to Bombay. Further, it is likewise demonstrated that if grass can be cut before it is dead ripe, a hay of considerably better quality will be obtained.

101. *Juar Fodder* (Sorghum vulgare).—In 1895-96 Mr. Subbiah, Principal of the Cawnpore Agricultural School, carried out an experiment, at my suggestion, to determine which of two practices common in the North-Western Provinces and Oudh is the better.

STATEMENT No. 18.

Showing the composition of the Juar Fodder reaped at different periods.

	Moisture.	Albuminoids.	Carbohydrates, starch, etc.	Woody fibre.	Mineral matter.	Albuminoid nitrogen.	Total nitrogen.	Insoluble siliceous matter.
			Composition in the fresh state.					
Juar fodder cut in October, Plot $2\frac{1}{1}$ (first cutting) . .	56·10	3·10	20·65	15·32	4·83	·496	·565	2·54
Juar fodder cut in March, Plot $2\frac{2}{1}$ (second cutting) . .	63·77	1·54	18·50	10·35	5·84	·247	·419	4·07
Juar fodder cut in March, Plot $2\frac{2}{2}$	48·78	2·01	25·31	15·92	7·98	·323	·428	5·88
			Composition of dry fodder.					
Plot $2\frac{1}{1}$, first cutting . .	...	7·06	47·04	34·90	11·00	1·13	1·28	5·78
Plot $2\frac{1}{1}$, second cutting . .	...	4·25	51·06	28·56	16·13	·68	1·15	11·24
Plot $2\frac{2}{2}$	...	3·93	49·42	31·08	15·57	·63	·835	11·48

In some districts, when the grain of *juar* (*Sorghum vulgare*) is cut off from the stems, the latter is removed from the field and stacked for subsequent consumption by cattle; in other districts the stalks are allowed to remain standing during the cold weather and only harvested later. Accordingly a plot measuring about $\frac{1}{3}$ acre of this crop having been grown, the seed was harvested in October. The stems of the plant were also removed from *one-half* of the plot and stacked; the stalks on the second half of the plot were allowed to remain until the following March. During the cold weather the plant on the first-half plot sent up new shoots and thus a second cutting from the first-half plot was obtained in March.

The details of the weights of fodder obtained are as follows:—

From first half plot 2,274 lbs. of fodder was obtained in October at the time of harvesting the grain; and the fodder obtained as second cutting in March weighed 478 lbs.; from the *second* half plot 1,998 lbs. of fodder was obtained in March. Thus, so far as weight of fodder is concerned, it proved infinitely better to remove the stalks and stack them in October; and, if the land be not required for another crop immediately, a second cutting may be obtained at the end of the cold weather.

In the accompanying statement No. 18 is set out the composition of these three lots of fodder.

In the upper section of the statement, the moisture present at the time of cutting is included; in the lower half, the water is excluded, and the composition of the perfectly dry fodder is shown.

It will be seen that the fodder which was stacked in October is very much the best, besides being the largest in amount, and that the fodder obtained as a second cutting in March is just as good as that from the other half plot which had remained standing all the cold weather. It need hardly be said that a question of this nature should be experimented upon several times in order to arrive at a result which cannot be doubted, but the experiment, so far as it has gone, speaks very definitely in favour of harvesting the fodder at the same time as the seed.

102. *Sorghum halipense.*—Another fodder crop which I have had an opportunity to examine is *Sorghum halipense* (sometimes called cuba grass), to which my attention was directed in 1894 by Major H. Goad, Superintendent of the Remount Depôt, Saharanpore. It had proved to be a most valuable fodder for horses, and as it appeared to yield heavily at Saharanpore, to ripen late, and to propagate itself very readily, I asked Major Goad to supply me with some of the seed, which he kindly did. One-half of this was sent to Nagpore, the other half to Poona, and it was sown at both farms.

Mr. Mollison, in his Report of the Poona Farm for 1895-96, says:—

"*Sorghum halipense* is an introduction from the Allahabad * Grass Farm and apparently will succeed admirably in the Poona District. The seed was sown early in July and the grass became fairly established in its first season. The land was laid out into long narrow beds at sowing time, so that, if necessary, the crop could be irrigated. It was allowed to run to seed. The seed was ripe early in November. Subsequently the plot was watered twice, but this grass has evidently a dead season; and even with irrigation it remained quite

STATEMENT No. 19.

Composition of Juar and Sorghum halipense (Nagpore).

	$\frac{18}{95}$ *Sorghum halipense* reaped green.	$\frac{19}{95}$ *Sorghum vulgare* reaped green.	$\frac{20}{95}$ *Sorghum halipense* reaped ripe.	$\frac{21}{95}$ *Sorghum vulgare* reaped ripe.	$\frac{22}{95}$ *Sorghum halipense* seed and chaff.	$\frac{23}{95}$ *Sorghum vulgare* seed.	$\frac{24}{95}$ *Sorghum vulgare* chaff.
Water	70·96	69·76	57·15	67·02	7·84	9·96	10·79
Oil	...	...	...	...	3·95	3·40	...
Albuminoids (N × 6¼)	·81	·55	1·22	·64	7·36	7·66	2·24
Soluble carbohydrates	12·14	14·74	19·17	16·42	53·47	74·44	51·57
Woody fibre	12·57	11·90	18·13	12·78	16·45	2·24	25·42
Ash	3·52	3·05	4·33	3·14	10·93	2·30	9·98
	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen (total)	·184	·113	·26	·173	1·35	1·26	·484
Albuminoid Nitrogen	·130	·088	·196	·103	1·18	1·23	·358
Sand	2·2	1·88	3·04	1·6	8·58	·63	6·94

dormant during the cold and hot weather. In May of the current year it began to send forth shoots, which, as soon as the rains came, grew with great vigour. The crop was in full flower and ready to cut as green fodder in the first week of July. The inflorescence is a much branched panicle, rich brown in colour. The crop, when in flower, has a very handsome appearance. The flower stalks stand about 5 feet high and are distinctly thin and fine for a grass of such vigorous habit of growth. Cattle like it. New shoots spring from

* Should be *Saharanpore.*

the rhizomes, which are under-ground stems. I have no doubt the grass, if once established in arable land, would on this account be difficult to get rid of. This, as far as I know, is its worst fault. It is certainly good enough to take a prominent place on land growing grass permanently. The first cut in the current year yielded 4,720lbs. of green fodder per acre, and I confidently expect that at least one other equally good crop may be expected before the rains have ceased. The rapidity of growth early in the monsoon is a valuable characteristic in the Deccan. The grass is ready just at the time when ordinary fodder is usually exceedingly scant and very dear."

Mr. Joshi, in his report of the Nagpore Farm for 1895-96, says of it :—

"*Sorghum halipense* seed was sown in a field along with *juar*. It is a fodder plant and is grown on the Shaharanpore Farm (Military). The yield was a poor one. Samples of the plant, cut in different stages of its growth, were sent to Dr. Leather for analysis, and his report is reproduced below. A point worth noticing in this plant is that the stump which remained in the ground continued sprouting and tillering all the year round. Even in the hot months of April and May I discovered some green blades about the plant when other grasses were all parched."

The *juar* was grown in a neighbouring plot for comparison's sake with the *cuba* grass, and the analyses in the accompanying statement No. 19 represent these two fodders in the green and ripe stages, respectively. It will be seen that, so far as composition is concerned, the *cuba* grass fodder contained, both in the green, as also in the ripe state, more albuminoids and about the same amount of carbohydrates, but also somewhat more woody fibre, than the *juar* fodder.

The outturn appears to have been unsatisfactory at Nagpore, but good at Poona, and, as Mr. Mollison says, it should prove an admirable grass for pasture lands. The seed is much smaller than *juar* and difficult to separate from the chaff, which detracts from its value as a food for human beings.

103. *Bhusa.*—This term is applied in India to the straw or chaff of a grain crop which is trodden out by cattle. In the case of the cereals and certain pulses, the whole crop, *i.e.*, stems and ears or pods, are trodden by the cattle, by which means, not only is the grain separated from the chaff, but the straw is also reduced to a fine state of sub-division. In other cases, such as the millets *Sorghum vulgare* and *Pennisitum typhoideum*, and the taller pulses, such as *arhar* (*Cajanus indicus*), the panicles or pods and leaves only are trodden by the cattle.

After separating the grain, the refuse stem, leaf, etc., is called *bhusa*, and forms the most valuable fodder in the possession of the cultivator. There is doubtless much valuable information to be gained from a careful examination of these various materials. I have only examined samples of six kinds, and the analyses are set out in the accompanying statement No. 20. The first three include the chaff as well as the straw; the peas and gram *bhusa* include some of the stem as well as the chaff; the *arhar bhusa* the chaff only.

STATEMENT No. 20.

Composition of Straw and Chaff of certain crops grown at Cawnpore.

	201/93 Wheat "bhusa."	202/93 Barley "bhusa."	203/93 Oat "bhusa."	204/93 Gram "bhusa."	205/93 Arhar "bhusa."	206/93 Pea "bhusa."
Water	7·56	7·93	9·53	10·11	6·58	9·88
Albuminoids (true)	2·37	4·00	1·37	4·46	7·39	9·94
Soluble carbohydrates	43·06	41·45	43·48	38·84	45·74	42·83
Woody fibre	34·68	34·82	36·09	27·63	25·69	22·27
Ash	12·33	11·80	9·53	18·96	14·60	15·08
	100·00	100·00	100·00	100·00	100·00	100·00
Nitrogen (total)	...	...	...	...	..	...
Nitrogen Albuminoid	·38	·64	·22	·71	1·18	1·59
Sand	11·77	6·25	5·81	9·30	8·87	5 73

CHAPTER VII.

Crops and Cultivation.

104. In treating of this subject Dr. Voelcker described the *cultivation* of crops in India as excellent, and pointed to the care with which much, if not most, of this part of the work of the Indian ryot is executed.

In the matter of *seed selection*, the opinion which Dr. Voelcker formed was far otherwise. He says, "though the ryot may have little or nothing to learn about rotation, he is very ignorant in regard to selection and change of seed" (paragraph 308), and he further urges the desirability of helping the ryot by introducing to him new varieties of crops and new crops altogether (paragraphs 311 and 312). In these views I entirely agree with Dr. Voelcker.

105. In the matter of cultivation there cannot be the least doubt that very great care is usually bestowed upon it. The way in which crops are generally cleaned of weeds is a striking example of this. Nevertheless in some cases, such for instance as in the cultivation of sugarcane, there is, as Dr. Voelcker has observed, unquestionably room for improvement. Between the method of cultivating this crop as practised in the Bombay Presidency and in parts of Bengal on the one hand, where the plants are ridged up, and later bound with the dry leaves to prevent them from falling, and the practice appertaining generally to Behar and the North-Western Provinces on the other, where the crop is grown on the flat, there is all the difference in the world. It cannot be suggested that the former is not better than the latter. Similarly in the careless and excessive use of canal water, we have an example of improvidence.

106. In respect of rotation, not only is this practice very general in the European acceptation of the term (for over large areas land bears one year a "kharif" and the next a "rabi" crop), but also many of the mixtures of crops grown, occasion a "rotation," as Dr. Voelcker pointed out. In some of these cases there is clearly more than one advantage. For example, when a leguminous crop as *tur* (*cajanus indicus*) is grown with one of another natural order as cotton or *juar*, in alternate rows, the millet or cotton comes on first and is harvested, and, then later, the *tur* grows apace and actually fills the whole field. Thus in, say, 9 months the field has been entirely occupied by two different crops, one of which has a growing period of about 5, the other about 9 months, and this too with one cultivation. This practice is to my mind an example of very great economy in a country where much that is most wasteful forms a part of its agriculture. In other cases of mixed crops I have not been able to discern any advantage. For example, what advantage can be suggested from growing wheat and barley mixed together, or wheat and mustard? One common explanation is that, by sowing two crops mixed, if the one fails, the other may succeed. I know of no reason why, in such instances as those cited, this is the case. Moreover, when two plants, *e. g.*, wheat and barley, occupy much about the same area in their growth, and ripen about the same time, it would answer the purpose just as well if they were grown in the separate fields. Protection against loss of crop would be just as surely maintained. Indeed, in some districts of the North-Western Provinces and the Punjab wheat and barley *are* grown separately and not mixed together; the two practices thus occurring in closely contiguous countries where difference of climate cannot be suggested as a reason. Again, in the case of mustard being sown with wheat, it is often said that the mustard is sown round the borders of the field as a protection against cattle trespass. But not only is the border of mustard so narrow that it becomes an absurdity to suppose that it does really protect the rest of the crop from cattle, but also it is extremely common to sow rows of mustard throughout the wheat and likewise to sow the two as a mixed crop, *i.e.*, without any regularity in the manner of sowing the mustard.

But we may go still further and point to the fact that *gram* (*Cicer arietinum*) is sown pure enough in some districts, whilst in others the *gram* is largely mixed with *kesari* (*Lathyrus sativus*), one of the most valuable pulses,

being thus hopelessly mixed with another, which is not only inferior in market value, but frequently positively harmful.

Thus, so far as the practice of mixing crops is concerned, we have very wide differences; in some instances an undoubted economy results, in others not only is this not the case, but one is forced to the conclusion that the practices in vogue are anything but good.

107. In paragraph 308 of his report Dr. Voelcker mentions several districts in which seed selection is more or less practised. In one part only have I myself observed seed selection carried out, namely, Gujarat, Bombay, and curiously it is named by Dr. Voelcker as a country where the practice is *not* customary. I have, however, seen it myself being done in the case of some of the millets, *juar*, and *bajra*, and I understand from Mr. Mollison that such a practice is quite common to the Province. (It is possible that a clerical error occurs in this paragraph of Dr. Voelcker's report.) Generally, as Dr. Voelcker pointed out, the practice is absent from Indian agriculture.

108. Turning now to varieties of crops, for some time after I arrived in India, I was under the impression that the cultivator in respect of many crops, such as wheat or the millets and especially rice, possessed a very perfect knowledge of what varieties are to be had, and that he knew what sorts suited his purpose best. My opinion has since been much modified in relation to this subject. Take, for example, the case of the wheat crop in Shahabad District, Behar. It is largely that which goes by the name of "Buxar" White Wheat, and this variety appears to have had such a good name that the Bengal Agricultural Department tried to introduce it into every district of the Province! Then came severe attacks of "rust" and it was found to be wanting in ability to withstand this disease.

The Dewan of the Dumraon Raj, by the advice of the Agricultural Department, then imported a large quantity of Muzaffarnagar wheat, and this variety has so far (*i.e.*, for two years) done well, and the people are very satisfied with the change. Moreover, on the Dumraon Farm, varieties of wheat from the Punjab, North-Western Provinces, and the Central Provinces have been grown alongside one another, and each year marked differences have been observed in the disposition of these several varieties to withstand rust, the Central Provinces varieties being uniformly attacked (although in neither year was the disease severe), whilst the Punjab and Muzaffarnagar varieties were almost free from attacks. Similarly, in the case of the sugarcane crop, it is said that the thick varieties, which go (in the North-Western Provinces) by the name of *pounda*, contain only a poor juice, from which *gur* cannot be made, and that the thin varieties usually grown for *gur* making contain a much sweeter juice, and that this is the reason why *gur* is universally made from the latter sorts. No greater fallacy could exist, for the *poundas* (or some of them) not only contain a juice quite as rich, or richer than, that in many of the small varieties of cane, but in addition there is a good deal more of it, some 50 to 55 per cent. of juice being extractable from the thin canes, whilst 65 to 70 per cent. is obtainable from the thick cane. Also in some parts of Bengal and Bombay sugar is regularly made from thick cane. Thus we have in the North-Western Provinces, for instance, sugar exclusively made from poor varieties of cane, whilst the better varieties are cultivated exclusively for chewing. What the real reason of this state of things is, is perhaps not clear; certain it is that the reason commonly advanced, that one cannot make *gur* economically from the *pounda*, is a fallacy. Again it is said that jackals and pigs attack the thick cane more readily than the thin, but whilst this may be the case, the difficulty can be overcome by introducing the Bengal practice of binding the dry leaves round the plant, a practice which is not known in the North-Western Provinces. But this is not all, for I am not sure whether another reason has not existed in the past. I am very doubtful whether the old *kholu* would have crushed the thick cane. Certainly the Punjab *belna* could not. On the other hand, the Bombay *gundi* or *cherki is* powerful enough, and here we find thick canes crushed for sugar. When the people had only the *kholu*, they grew the cane which they could crush. The iron mill is comparatively new introduction, and it will be some time before the people can

have demonstrated to them the fact that they can crush the thick cane. Finally, if the thick canes are to be grown successfully, the whole system of cultivating cane in the North-Western Provinces will require alteration, and when it is remembered how long it takes to alter anything, however bad, in the cultivator's practices, it will become evident that any change in the direction indicated must take a long time. I have referred to the question of sugarcane somewhat fully because I have been constantly told that the cultivator has "very good reasons" for growing those varieties of crops which he cultivates. Doubtless he *has* good reasons. He grows those varieties which he has in his possession. But if one finds better varieties elsewhere, surely it is sound to try to show him their advantages; or in the case of sugarcane to show him that, for whatever reason he may have cultivated poor varieties for generations for sugar-making, there are other varieties within reach which are infinitely better, although when altering his variety it may be necessary for him to alter his long continued methods of cultivation.

109. Generally, with regard to selection of seed and varieties of crops, it must be admitted that Dr. Voelcker's criticisms is amply justified. Whilst in Europe and America there is no branch of agriculture more energetically pushed than that for the provision of both good seed and new varieties, in India there is, for all practical purposes, no such agency. The Government Farms have tried to do something, as also have the Botanical Gardens, and these attempts have been by no means fruitless. But is it to be supposed that such very limited agency (for there are but six experimental farms in the whole of India, and these are mostly quite insufficiently manned) can really deal effectually with such a matter as the provision of seed for the body of Indian cultivators? I think not! If there were a body of *educated* agriculturists, such as one has in Europe and America, who could form Agricultural Societies, then a few principal stations could do something by working in conjunction with such bodies. But there is not only an almost entire absence of agriculturists among the educated classes of India; in addition, we have the fact that the people are largely indebted to the village *bunya* who is the "seedsman" of the people, and it cannot of course be supposed that he will trouble himself very much about varieties of crops. With such a set of circumstances it is in no sense surprising that selection of seed and the introduction of new varieties in India are fields of practical improvement almost untouched at the present day.

110. *Sugarcane.*—The foregoing paragraphs refer to methods of cultivation, selection and varieties of crops generally.

I must now refer in some detail to one crop, namely sugarcane, to the examination of which I have devoted a good deal of time during the cold weather harvests of 1894-95, 1895-96 and 1896-97.

The results of the chemical investigations have been published in the Agricultural Ledger (Medical and Chemical Series 1, 4, and 9).

The plans of the field experiments which have been started at Poona, Cawnpore, Dumraon, and Burdwan will be found in the annual reports of the farms in question. It need hardly be said that these field experiments have only been commenced, and the programmes which have been entered upon will certainly require some years for their completion. The plan of these field experiments is briefly detailed in Chapter X of this Report.

Lastly, that part of the work which has related more particularly to varieties of sugarcane will appear later in a joint paper by Mr. Mollison and myself. Thus most of the work has been published in detail elsewhere, and it will suffice for the purpose of this report if I explain concisely the directions in which the investigation has been started, and the results arrived at.

111. As explained in paragraph 147, Mr. Ozanne suggested experiments on sugarcane at Poona in 1894, and a few preliminary enquiries convinced me that there was a very extensive field of useful work in connection with this crop. In the Poona District it had been shown by crop experiments that a yield of 6,000 or 8,000 lbs. of raw sugar per acre was quite common. Moreover, the cane they grow there was a thick *pounda*. In the North-Western

Provinces, on the other hand, only thin canes are grown for sugar-making and a yield of 2,000 lbs. of raw sugar per acre is considered very good. Also it was generally said that one could not make sugar from thick canes.

Add to this the fact that practically nothing was known of the proportion of sugars in the juice of any of the Indian varieties of cane, or of the raw sugar made, and it will be evident that Dr. Voelcker's remark regarding this crop, that "there is sufficient work to call for the employment of a chemist for the purposes of that industry alone," was by no means an exaggeration.

Too large a programme could not be inaugurated at once, and experiments were therefore commenced early in 1894 at Poona and Cawnpore; the experiments were then extended in the following year to the farms at Dumraon and Burdwan.

The field experiments included the following :—

(*a*) The comparative value of different manurial materials for the crop (at all the four farms).

(*b*) The application of varying amounts of the same manure, with a view to determine how much may be economically applied (at all the four farms).

(*c*) The application of manures at different periods of growth; a part of the full allowance of manure was applied at the time of planting, the remainder being applied around the plants when the crop was a month or two old (at Poona only).

(*d*) The application of varying amounts of irrigation water to determine whether any economy could be effected in this respect (at Poona only).

(*e*) Harvesting the crop at different stages of growth in order to determine at what period it will yield the best results (at Poona only).

(*f*) Growing the crop repeatedly from the same stools, called *ratooning*, in order to determine how many *ratoon* crops may be taken economically (at Poona, Dumraon, and Burdwan).

(*g*) The cultivation of cane on the flat, and on ridges, respectively (at Cawnpore, Dumraon, and Burdwan Farms).

(*h*) The propagation of cane from the top ends only, and from the whole cane respectively (at Cawnpore and Burdwan).

(*i*) The cultivation of varieties of sugarcane (at all the four farms).

It cannot be said that any of these questions have been completely worked out, nor could it be anticipated that in so short a time such would be the case.

In relation to the experiments with manures it may be said that the Poona experiments have indicated that 20 tons per acre of poudrette manure, containing about 500 lbs. of nitrogen, has given very heavy crops, larger indeed than good ones around Poona, and, moreover, this quantity of manure is probably considerably less than many of the cultivators commonly apply.

At Cawnpore and Dumraon the best crops obtained have been manured with a less quantity than that above indicated; but the programme of experiments at these farms were considerably altered in 1896 after some experience had been gained. Moreover, the best crops at these farms were not nearly so large as those at Poona.

Some manures have been shown (even when applied in quantities containing corresponding amounts of plant food) to yield very different results from others. Farm-yard manure, for instance, appears to act very slowly, and one of the manure cakes (*Bassia latifolia* refuse) apparently destroyed the crop on one occasion. But definite results cannot be expected from this section of the work for some time to come.

The cultivation of cane from the top ends only is practised in some parts of Bengal, and may be elsewhere, but it is not at all a common method of propagating the plant, and as will be explained in paragraph 118, it is probable that it is an economical method to adopt.

The cultivation of sugarcane on flat ground, as generally practised in the North-Western Provinces and Behar, is undoubtedly a bad method. There cannot be the least doubt that this crop is damaged by being flooded, and that it should be ridged up with earth, as is the practice when growing potatoes. The field experiments have also uniformly demonstrated this.

The experiment with varying amounts of irrigation water has shown so far, that the best quantity varies with the season; up to the present the best crops have been obtained with the aid of $\frac{1}{2}$ or $\frac{3}{4}$ the normal supply.

The cultivation of different varieties has shown that great care will have to be exercised in judging whether a certain variety has been grown under normal conditions, for the proportion of sugar in the juice (and may be also the proportion of juice expressible by the mill) seems to become affected either by transference to any long distance or by change of conditions of cultivation.

112. These are briefly the subject matters which have been included in the field experiments. It would have been an advantage to plan out similar ones at the Nagpore Farm. But I have had no opportunity of becoming acquainted with the agriculture of the Central Provinces, and in addition I found that the chemical part of the investigations at the four farms named, fully occupied my time during the period in which the crops concerned were being harvested; as is well known, this crop matures at much the same period in Upper India generally. Without extra assistants it was impossible for me to extend the field of operations.

113. *The chemical investigations.*—In addition to the field experiments just sketched out, it is obviously of importance to enquire at the same time somewhat fully into the proportions of sugars in the cane, in the juice, and in the raw sugar, in order to determine what losses occur during the manufacture, and whether any of these could be reduced. The analyses of the juice, of varieties, has also led to important results. This part of the work has been published each year in the Agricultural Ledger (*vide* Medical and Chemical Series Nos. 1, 4, and 9).

Before explaining the results obtained, it will be well to mention one or two points connected with the analyses.

The analyses of the juice were in all cases executed in camp, at the fields where the cane was crushed, and all question of fermentation was thus excluded. The cane-sugar was determined by the polariscope and the glucose by Fehling's method.

The analyses of raw sugars were in part performed in camp, in part at the laboratory, but as no question of fermentation here interferes, this part of the work was performed whenever it was found to be most convenient.

The analyses of the cane could not be performed in camp, principally for want of the necessary time, but also because some of the operations could not be executed under such circumstances. The cane had to be sent to the laboratory, but in order to determine any loss of moisture which would occur during transit, the samples were weighed when freshly taken out of the field, and again on receipt at the laboratory before the analysis was commenced.

114. The investigations may now be conveniently referred to under the following heads:—

(1) The composition of the juice—(*a*) in cane which had been transferred to long distances; (*b*) in cane which had been grown with varying amounts of manure; (*c*) in cane which had become *lodged*; (*d*) in the top ends of the cane; (*e*) in different varieties of cane.

(2) The relation between the amount of sugar in juice and its specific gravity.

(3) The determination of the amount of inversion which takes place during the concentration of the juice.

(4) The amount of sugar which becomes lost in the scum.

(5) The composition of the raw sugar, *gur*, *gul* and *rab*.

(6) The refining of sugar by means of the hand centrifugal separator.

(7) The total amount of sugar in cane and the amount remaining in the crushed cane.

(8) The amount of phosphoric acid and nitrogen in the sugarcane crop.

115. (1-*a*) *The composition of the juice of cane which had been transferred to long distances.*—In the course of the experiments under reference, several varieties of cane have been transported to considerable distances. In 1894 two varieties were sent from the Mauritius to Poona, one a white and the other a red variety. They were grown at Poona with very liberal amounts of manure, and so far as appearances went, both crops were splendid. They were reputed to give a juice containing some 18 per cent. of sugar. But at Poona the juice of both has contained much less than this amount. In 1895 the juice of the white variety contained about 12 per cent. of cane-sugar and 1·4 of glucose; that of the red variety about 10 per cent. cane-sugar and 2 of glucose. In 1897 (the third crop) the corresponding figures were 14·71 per cent. cane-sugar and ·99 of glucose in the juice of the white and 12·7 of cane-sugar and 1·5 of glucose in that of red variety. Thus, although the juice is still poorer than it ought to be, a material improvement has manifested itself during the three years.

A second example of this nature occurred in the case of the Poona *Pounda*, the variety commonly grown around Poona. This cane at Poona has been found to contain from 16—18 per cent. of total sugar. It was sent to Cawnpore and Dumraon in 1895, but the crops at both farms produced a juice containing only 14 per cent. of total sugar in the 1895-96 crop, and there was just about the same amount in the crop of 1896-97.

Some further evidence was gained during the past season. A number of varieties, commonly grown in the Bombay Presidency, were collected in 1895 and grown at Poona in 1896. These crops were then analysed in the past cold weather. Immediately afterwards I visited villages in the neighbourhood of Belgaum and Dharwar, and analysed some of these same varieties in their native place, and it was then found that in three cases the quality of the juice was much lower, in two instances it was higher, and in one it was the same at Poona as in the crops at Belgaum and Dharwar. Thus the evidence at hand points to the conclusion that transference of cane from one country to another *may* cause a material alteration in the development of the plant, generally resulting in depreciation of the juice. The evidence given by the Mauritius varieties, however, indicates that the cane will gradually assume a normal composition in the course of a few years.

116. (1-*b*) *The composition of the juice of cane which has been grown with varying amounts of manure.*—One of the questions which naturally presented itself at the commencement of the experiments was, "what effect has manuring on the quality of the juice of sugarcane?" The plots at Poona and at Cawnpore received in each case very varying amounts of manure, and the question appeared to be one which would be readily solved. Accordingly, one or more samples of the juice of the cane from each of the plots in question at these two farms, was analysed during the harvest. The results at first obtained are quite uniform.

The cane at Poona (*pundia*) was grown with a series of different manures, varying very much in amount; the nitrogen from 130 to 1,000 lbs. per acre, and the phosphoric acid from 140 to 2,700 lbs. per acre; in all cases the amount of manure was large. The percentage of both cane-sugar and glucose was found to be very constant in each year, namely, from 15 to 17 per cent. of cane-sugar and 1·0 to 1·8 per cent. of glucose.

At Cawnpore a small cane, the *matna*, was grown in 1894-95 and 1895-96 with different descriptions of manure, in varying amount (the nitrogen varied from *nothing* on the unmanured plot to nearly 200 lbs. on the most heavily manured lot); the weight of manure being in all cases very much smaller than was the case at Poona. Again the analyses of the juice of this cane showed no relation between the amount of manure applied and the quality of the juice; the cane-sugar varied from 14 to 17 per cent. the first year and from 15 to 17 per cent. the second year, and the glucose from ·3 to ·5 per cent. Thirdly, at Cawnpore in 1896-97 another variety was grown, a

thick *pounda* called *madrasi*, and this was manured with different materials containing from 250 to 500 lbs. nitrogen per acre, the amounts being in every case *large*. The percentage of cane-sugar varied from 14 to 15·5 per cent., and the glucose from ·5 to ·9 per cent.

Thus the evidence adduced from three somewhat extensive series of tests pointed uniformly to the conclusion that neither the kind of manure, nor its amount, exercised any influence on the quality of the juice of sugarcane.

It so happened, however, that conflicting evidence was met with during the cold weather of 1896-97 at Cawnpore. Six varieties, three thin ones and three thick ones, have been grown at this farm for three years. One of these was the *matna* variety already alluded to. In 1896 it was decided to grow this variety (along with the others) with large amounts of manure. It now grew much taller than usual, and the weight of crop was much increased. When, however, the juice came to be analysed, it was found that, instead of containing the 15 to 17 per cent. of cane-sugar which had been maintained for two years, the proportion had fallen to 11 per cent.; on the other hand, the proportion of juice expressible by the mill, which had previously been 45 to 50 per cent., was now found to be 60 per cent.

Another piece of similar evidence was obtained in connection with the Dumraon experiments, where it is probable that high manuring had, in the case of *certain* canes, reduced the proportion of sugar. But a consideration of the evidence on this subject clearly offers an explanation of the effects noticed.

It is certain that *under the conditions of growth* of the Poona *pundia*, the *matna* in 1894-95 and 1895-96 and the *madrasi* in 1896-97, manuring had *no* material effect; and those conditions are readily set out. The Poona cane is commonly grown with large amounts of manure, and it was similarly supplied, in the experiments. The *matna* is commonly grown with only small amounts of manure, and only small amounts were supplied to it at Cawnpore in the first two years. Thirdly, the *madrasi* variety is commonly heavily manured, and the treatment for it was similar in this respect at Cawnpore in 1896-97. Thus, *while the conditions of manuring assimilated to those to which the several varieties are accustomed*, the proportion of sugar remained normal, whereas, if the one or two cases of sudden change in the composition of the juice due to heavy manuring are to be relied on, it would appear that a variety *may* produce a poor juice, if it be suddenly grown with much larger amounts of manure than those to which it has been accustomed for long periods.

It must not be supposed, however, that a less outturn of sugar was realised in the case of the *matna*. Although the percentage of sugar in the juice was less, much more juice was obtained, and the crop was about twice as heavy. So that from the economic point of view there was a considerable gain. Moreover, the evidence, such as it is, of the varieties at Dumraon, point to the fact that under the new conditions, the varieties will regain their normal growth in the course of a few years. The case is indeed very similar to that referred to in paragraph 115, where the effect of change of climate is discussed, and it seems likely that a cane may suffer from either cause; the effects are however probably only temporary.

117. (1-*c*) *The composition of the juice of cane which had become lodged.*—The crop of cane at Cawnpore was much lodged in 1894 by rain, and it was decided to crush the fallen cane separately from that which remained erect. It was then found that the juice of the lodged cane contained *much* less sugar than that in the standing cane, and the *gur* prepared from it was so full of molasses that it would not solidify. In the other two years the weather was not abnormally wet, and no further evidence of the effects of heavy rain have been obtained; but the crops at Cawnpore and Dumraon were so heavy in 1896 that some parts fell down. The juice of the fallen cane was again separately examined, with the result that it was found to contain generally a less proportion of cane-sugar, and a larger one of glucose, than was found in the standing cane. The differences were on the whole not great, and nothing like so serious as was the case with the crop which had been *lodged by rain* in 1894.

118. (1-*d*) *The composition of the juice of the top ends of the cane.*—My attention was directed to the quality of the juice in the top ends of the cane, because in the Burdwan District of Bengal it is customary to propagate the crop from the top ends only, whilst in most parts of India the usual practice consists in cutting up whole cane into pieces and propagating from them.

Moreover, it so happens that in no part of India is the cultivation of cane, in most respects, more perfectly carried out than at Burdwan, and one at least of the varieties there grown, is an exceptionally good one containing from 16 to 18 per cent. of sugar. In no respect, therefore, could it be said that the quality of the cane or the cultivation was inferior. Now the weight of cane which is used for sowing is very considerable, amounting to several thousand pounds per acre, and the question naturally presented itself, what sort of juice is contained in the top end of the cane, and is it an economy in the matter of sugar to propagate from the top ends only? Accordingly, several sample bundles of cane were taken at Burdwan this year, the top ends cut off, and the juice expressed and analysed from the top ends and the remaining cane, respectively. The experiment showed quite conclusively that there was much less juice in the top ends than in the main part of the stem, and much less sugar in that juice. Consequently it is apparent that, if an acre be sown with the top ends of the cane, and the main part of the cane be reserved for sugar-making, an economy in sugar will result. Taking the figures which were obtained in the experiment as a basis of calculation, this economy amounted to about 320 lbs. of raw sugar in the case of one variety, and to about half that amount in the case of another; or we may say that by propagating from the tops only, a saving of several hundred pounds of raw sugar per acre will be realised.

It appeared desirable that other varieties should be propagated from the top ends only, in order to determine whether any deterioration of quality resulted, and this is being done at Cawnpore with cane which has always been grown from the cut-up whole cane; but unless such deterioration should manifest itself, it must mean a great saving to cultivators to plant from the top ends only.

119. (*1-e*) *The composition of the juice of different varieties of cane.*—The amount of juice expressible by the mill, and the proportion of the cane-sugar and glucose in the juice, has been determined for a number of varieties, some of which have been grown at the farms, some in villages at a distance from them. The amount and quality of the juice has varied a good deal between the worst and the best.

The proportion of juice expressible will be dealt with under (7).

The juice of the better varieties such as the Poona *pundia*, the *samsara* of Bengal, and the *madrasi pounda*, all contain high proportions of sugar varying from 14 to 18 per cent. of total sugar, and I am certain that no better cane can be obtained anywhere than these. Some of the thin varieties, too, such as the *matna* of the North-Western Provinces, *mungo* of Behar and *khari* of Bengal, give a juice containing similarly high proportions of sugar. On the other hand, some such as the *dikchan* and *dhaul* of the North-Western Provinces have much less sugar in their juice. Of the total sugar, the greater part is of course cane-sugar.

The glucose has in most cases been determined in the juice also, and its proportion varies from a half up to two per cent.

The acidity in the juice was determined in a number of samples in 1896, but the results obtained I considered uncertain. The colour of the juice is so dark that a difficulty was experienced in using "indicators." The question of the amount and kind of acidity is nevertheless an important one, for as will become evident when explaining the experiments which I made to prevent inversion when boiling the juice, this constituent causes a serious loss of crystallisable sugar. What is required is a method, both simple and rapid, for determining the amount of organic acids, other than carbonic acid, which may be used in the field, and I had not time to work one out.

120. (2) *The relation between the amount of sugar in sugarcane juice and its specific gravity.*—Owing to the increasingly large number of analyses

of juice which it was desirable to make in connection with these sugarcane experiments, and also to the fact that a chemist is only occasionally at the farms at the time of harvest, the need became apparent of some simple method of determining approximately the amount of sugar in juice.

In the case of sugar being dissolved in pure water, its amount may be determined with very fair accuracy by observing the specific gravity of the solution, there being a very simple relation between the two.

Sugarcane juice is not, however, a solution of only sugar in water; other substances are present besides, which affect the density. It occurred to me, however, that the amount of these other substances might be fairly constant, and if so, the insertion of a uniform correction would enable one to calculate the percentage of total sugar from the specific gravity.

Accordingly I compared the specific gravity of a large number of samples of juice with the amount of sugar actually found by analysis. The result of this was, that the difference between the percentage of sugar as shown by the hydrometer, and that actually present, proved to be fairly constant as I had expected. This difference amounted to about 2 per cent. in the majority of cases, and I calculated out a set of tables by means of which any one can find the per cent. of total sugar with the aid of a hydrometer. Of course such a method is only approximate, but the result will not be more than half a per cent. from the truth. Also it is to be observed, one only learns the amount of *total* sugar by this means, but since the amount of glucose is only small, the method will be found very useful for field work, when the more exact methods of the chemist are not available.

121. (3) *The amount of inversion which takes place when boiling down the juice.*—All cane juice contains organic acids, and these at a boiling heat possess the unfortunate property of converting a part of the crystallisable cane-sugar into uncrystallisable glucose. So far as the *food value* of the resulting sugar is concerned, the change is probably of no great consequence.

But in other respects the change is very serious. Not only are molasses useless and inconvenient to the refiner, to the small native refiner, just as much as to the large operator with European appliances, but to the *bunya* who has to store the *gur* or *gul* through the rains, the matter is of equal importance, because the larger the proportion of molasses, the more liable is the *gur* to liquefy in his *godown*. I found that, whereas in *the juice* each 100 parts of total sugar includes usually from 2 to 10 parts of glucose, in the *gur*, as ordinarily made, the proportion of glucose ranged from 10 to 20 parts. In addition, it is to be borne in mind that each part of glucose will prevent an equal weight of cane-sugar from crystallising, so that these figures have to be doubled in order to express the true effect of this glucose formation. In endeavouring to find a means of preventing the change, it was necessary to employ only such a method as the ordinary cultivator could use, and I believe I have more or less succeeded. The addition of a small quantity of quick-lime in water will neutralise the acidity of the juice, and thus prevent in a great measure the process of inversion. Too much lime must not, however, be employed, otherwise the resulting sugar becomes black, and its market value decreased. Litmus paper was at first employed to detect when sufficient lime had been added; later I found that there is a natural colouring matter in the juice which could be equally well employed.

The result of the careful addition of lime is to prevent very materially the formation of molasses, and the *gur* obtained has a much better crystal. That which has been made at Cawnpore has realised a distinctly higher price in the bazar than that produced by simply boiling down the juice. Likewise in some experiments which I made in villages on Messrs. Thomson and Mylne's Estate this year, the results were equally satisfactory.

122. (4) *The amount of sugar which becomes lost in the scum.*—When boiling down the juice, scum rises to the surface and is skimmed off more or less perfectly with ladles. The amount of this scum is considerable, and it seemed desirable to make one or two determinations of the amount of sugar which must of course be carried along with it.

Accordingly in the cold weather of 1895-96 I estimated very accurately the amount of sugar actually present in the juice, and later, after the *gur* had

been made, the amount of sugar in it. The difference between these two amounts is due to the sugar which had been carried away in the scum. Four experiments were made at Cawnpore and four at Poona. The loss of sugar proved to be from 10 to 14 parts per hundred in the juice.

This sugar, which is unavoidably taken in the scum, is, however, not wasted. At Poona the people recover part of it by putting the scum into water, boiling the liquid and again skimming off the scum; at Cawnpore the scum is given to cattle as a food.

123. (5) *The composition of the raw sugar.*—By far the greater part of the cane juice produced in India is simply evaporated down (after removing the scum) to such an extent that on cooling the mass becomes solid. This description of raw sugar is called *gur* in the North-Western Provinces and Bengal; in the Deccan it is called *gul*. Whilst still hot, the raw sugar is usually run into moulds where it solidifies in blocks weighing from 25 to 100 lbs. Sometimes, as in parts of Oudh, the *gur* is made up whilst warm and soft into rounded pieces about a couple of inches diameter, and again in other districts, *e.g.*, Dehra Dun, it is run out on bamboo matting whilst hot and allowed to solidify in thin cakes. These are, however, minor practices, and are not deserving of recommendation. Some of the Oudh *gur* proved to be exceedingly dirty.

The composition and colour of this description of raw sugar will vary very considerably, much depending on both the quality of the juice and the mode of working.

If the cane becomes *laid* by rain, the juice will contain a high proportion of glucose (*vide* paragraph 117) and the resulting *gur* will be soft. Again, if the juice be poured through a cloth or brass wire strainer, much dirt and bits of cane are separated; it is indeed surprising how much dirt can be removed from the juice by this means. During the boiling process the more perfectly the skimming is effected, the purer will be the product and the better its colour.

Finally, if the acidity of the juice be neutralised, the *gur* will contain a lower proportion of molasses (*vide* paragraph 121.)

Some samples of cultivators' *gur* from Oudh which I analysed, contained of cane-sugar from 63 to 72 per cent., glucose from 9 to 10 per cent., mineral matter from 3 to 4 per cent., water and other impurities from 15 to 24 per cent.

The samples of *gur* made from *laid* cane at Cawnpore in 1895 contained from 64 to 68 per cent. cane-sugar and 13 to 14 per cent. glucose, whereas the *gur* from the erect cane of the same crop contained from 70 to 75 per cent. cane-sugar and 8 to 10 per cent. glucose. But with good cane and careful manufacture, the *gur* will contain from 70 to 78 per cent. cane-sugar and from 5 to 15 per cent. of glucose.

124. In addition to the solid *gur* or *gul*, another description of raw sugar is prepared by removing the mass from the fire at a somewhat earlier stage, and before all the water has been boiled out. The resulting sugar never solidifies entirely, but a great deal of the cane-sugar crystallises out during the first few days, and the mass becomes semi-solid. It goes by the name of *rab* in many parts, but in parts of Bengal it is also called *gur*.

The composition of *rab* will vary somewhat according to the amount of water which is left in it. That made at Burdwan this year contained from 65 to 73 per cent. cane-sugar and 5 to 19 per cent. glucose, but one of the samples was undoubtedly below average for some reason or other. Other samples from Behea, which were prepared in my presence, contained from 69 to 75 per cent. cane-sugar and only 2¼ to 5 per cent. glucose, and there is no doubt that, given good cane and careful manufacture, the latter standard can be maintained.

This description of sugar is prepared specially for the purpose of refining. Frequently it is put into sacks which are then placed one on another in order to increase the pressure on the lower ones, and the molasses gradually run out more or less. Or again the refining process is effected by placing the *rab* in a vessel having a "false bottom." A wet weed (*sewar*) is then placed on the surface, and the molasses gradually leave the top layer of sugar. This purified layer is then scraped off, and the *sewar* applied to the next layer, and so on

until the whole has been refined. In neither of these refining processes are the molasses obtained in a fit state for human consumption, and this means a loss of fully one-third of the sugar operated upon.

One sample of sugar refined by this process contained 96·6 per cent. of cane-sugar and ·89 per cent. glucose.

125. (6) *The hand centrifugal sugar separator.*—Another much better means of separating the molasses from the sugar crystal of *rab* has been provided by Messrs. Burrows, Thomson and Mylne of Behar, who have introduced a centrifugal machine, worked by one man at a time, by means of which the molasses are separated in a few minutes. About 25 seers of *rab* are placed in a machine at once, the separation is effected in about 20 to 30 seers, and the resulting sugar removed and the machine cleaned out ready for the next charge within 5 minutes. About 50 maunds of *rab* can be readily worked off in one day by each machine. The molasses are recovered quite clean and sweet and are boiled down to form solid *gur*.

The proportion of clean crystallised sugar (what is called *brown sugar* in England) which is obtained, will of course vary somewhat with the nature of the *rab* operated upon. In one of Messrs. Thomson and Mylne's experiments a yield of 40 per cent. was obtained, in another 52 per cent. In two experiments which I made 48·8 and 51·9 per cent. was obtained.

The amount of *gur* obtained after boiling down the molasses seems to vary between 25 and 40 per 100 of *rab* operated upon.

The so-called "turbine" or "centrifugal" sugar is very fairly pure. I have analysed several samples, from which it appears that it contains from 90 to 95 per cent. of cane-sugar, from $\frac{3}{4}$ to 2 per cent. of glucose, from $\frac{1}{2}$ to 3 per cent. of moisture, from $\frac{3}{4}$ to $1\frac{1}{4}$ per cent. of mineral matter, and from 2 to 3 per cent. of other (organic) impurities.

The *gur* obtained by boiling down the molasses is quite as good as much of the *gur* which is made by the cultivator direct from the juice. Judging by the composition of some samples which I have examined, it appears to have about the following composition: cane-sugar from 65 to 80 per cent., glucose from 5 to 14 per cent., mineral matters from $3\frac{1}{2}$ to 4 per cent., water and other impurities from 10 to 20 per cent.

In addition to a regular trade which has sprung up in the Shahabad District in "centrifugal" sugar, which is exported long distances by rail, a similar trade has arisen in the *gur* made from the molasses. I believe that a great future exists for this hand centrifugal machine, for it is clear that a very material economy in sugar must take place by its means over the native processes in which the greater part of the molasses becomes unfit for human consumption, and thus actually lost entirely so far as food-supply is concerned.

126. (7) *The total amount of sugar in sugarcane and the amount remaining in the crushed refuse.*—Since it is obvious that by no process of simple crushing, all the juice can be expressed from cane, it becomes an interesting question, how much is left with the refuse?

The matter is of far greater importance than might at first sight appear. It has generally been assumed in India that everything related to the crushing process depends entirely on the mill, and the question of difference in the variety of cane has rarely, if ever, been considered.

The first year's crushing of cane at the farms brought a very important fact to light. At Poona about 70 per cent. of juice was obtained from the cane there grown; at Cawnpore only about 50 per cent. was expressed. Since the mills which were used at the two places were essentially different, one might have said that the mills at Poona were infinitely better than those at Cawnpore. I knew, however, that such was not the case, some of the mills at Cawnpore having been of the very best workmanship and pattern.

The difference between 50 and 70 per cent. of juice is so great, that I decided to make some careful experiments in 1896 to find out what the true state of the things really was. Accordingly the total amount of sugar and of juice was determined in two lots of the Poona cane at Poona, and in five different varieties grown at Cawnpore. The amount of juice expressed was

also known, as well as amount of sugar in the latter, and the difference between the two gives the amount left in the crushed refuse cane.

(It may be here mentioned that I found it impossible, for technical reasons, to determine the amount of sugar in the refuse *directly*. When working in the field out of reach of any laboratory, only certain appliances can be used, and I had therefore to be content with taking the *difference* figure above indicated, as representing the quantity of sugar in the refuse.)

The methods employed are sufficiently clearly set forth in paragraphs 11 to 13 of Agricultural Ledger No. 19.

The result of this investigation showed quite clearly on what factor depends the amount of juice which a good mill can express from sugarcane. The total amount of juice found in the two extreme cases examined varied from 85·2 to 91·5 per cent. The amount expressed from 45·4 to 72·2 per cent. A comparison of these figures throws no light on the subject, for there is obviously no simple relation between the two cases, in one 45 out of a total of 85 and in the other 72 out of a total of 91 per cent. of juice.

If, however, another item in the composition of cane, namely, the *fibre*, be brought into the comparison, and its effect be considered, the cause of these variations in the amount of juice expressed becomes evident.

It will be readily understood that so soon as cane is crushed up by the mill and the cells opened, the only physical force which prevents *all* the juice from running out is that of adhesion. The fibre of the cane becomes, in fact, a spongy material, and just as it is impossible to press all the water out of a wet sponge, so likewise is it impossible to express all the juice out of cane.

But the analyses of the several varieties showed further that *quite independently of the variety*, the *crushed* refuse cane contained approximately always the same amount of juice. At Poona the crushed cane consisted of 70—71 per cent. of juice and 29—30 per cent. fibre; at Cawnpore with entirely different mills and other varieties of cane, the refuse consisted of 72—75 per cent. of juice and 25—28 per cent. of fibre.

Thus the proportion of juice in the crushed cane remained approximately constant, *i.e.*, the fibre of these different varieties held approximately the same amount of juice in each case. Referring again now to the instances already alluded to, in one of which a cane contained 85 per cent. of juice and yielded only 45 per cent. at the mills, and in the other, the cane contained 91·5 per cent. juice and yielded 72 per cent. at the mills, if the amounts of crude fibre present in these canes be considered, its effect becomes apparent. The former contained 15 parts of fibre per 100 of fresh cane, and this 15 of fibre held 40 parts of juice, allowing only the other 45 parts to run out when pressed. In the second cane, 100 parts contained 8·5 parts of fibre and this 8·5 parts of fibre held 19·5 parts of juice, allowing the remaining 72·2 parts to run out when pressed. And, as a result of this investigation, it may be said that, even with the best of mills, each part of fibre in the fresh cane will hold twice to two-and-a-half times its own weight of juice when pressed, and allow only the surplus to run out.

It becomes therefore an all-important matter in the selection of varieties of cane to choose those which contain low proportions of crude fibre. Speaking generally of varieties, I have found it almost uniformly the case that the small varieties commonly grown for crushing purposes in the North-Western Provinces and Behar, contain high proportions of crude fibre, and yield only some 50 to 55 per cent. of juice at the mills. On the other hand, the thick canes, some varieties of which are grown for chewing in the North-Western Provinces, others for crushing in Bengal and the Deccan, contain uniformly low proportions of crude fibre, and yield from 65 to 70 per cent. of juice at the mills.

Thus, even assuming that the juice of the thin varieties is just as rich in sugar as that of the thick ones (and it is probable that it is not so rich), the introduction of thick varieties in place of thin ones, would mean a direct gain in sugar production of about 25 to 30 per cent. over that at present obtained, and this without any further expenditure on manure, water, etc.

127. (8) *The amount of phosphoric acid and nitrogen in the sugarcane crop.*—As mentioned in paragraph 147, at Poona the cultivators

employ very large amounts of manure for this crop, and it has been further demonstrated by the field experiments that, whilst it may be the case that these amounts are somewhat larger than is necessary, very heavy dressings of manure *are* desirable, and will readily repay the initial cost. So far as one can draw any conclusion from the three years' experiments, it would appear that 500 lbs. of nitrogen per acre should be given in order to obtain a full crop. The amount of phosphoric acid required is still quite uncertain. Since it is necessary to apply such large amounts of manure, it seemed desirable to gain a knowledge of the amount of these plant foods which are extracted from the soil by cane crops generally, and I made several determinations to this end. The cane, green tops, and dry leaves of crops at Cawnpore and Dumraon were weighed, and portions of each submitted to analysis. The results obtained showed that in crops weighing 60,000 to 70,000 lbs., there was generally contained some 50 to 60 lbs. of nitrogen and the same amount of phosphoric acid. The crops at Poona are fully twice as heavy as this, and it may therefore be said that they remove 100 lbs. or more of each of these plant foods. There is consequently a considerable balance unaccounted for. In paragraph 150 I have examined the results of the analyses of the Poona (*manjri*) farm soils, and judging by these, this balance of plant food is still in the soil, and no material amount has been lost by drainage up to the present.

128. *Concluding remarks.*—As to the general importance of experiments on the sugarcane crop, it is almost unnecessary for me to say anything. It is clear in the first place that so long as India has to import sugar (the net amount is about 75,000 tons annually), there is room for an increased production. It is also clear that, whilst an article of diet, which is common to the people generally, is imported, the cost of production is higher than it should be. But this is not all, for the greater part of the sugar produced goes to the cities, and it thus becomes in a measure a luxury. Then, too, there is the difference between the outturn per acre as realised in the Deccan and Bengal on the one hand, where, with good varieties and good methods of cultivation, some 2½ to 4 tons of raw sugar is obtained, and in Behar and the North-Western Provinces on the other, where the outturn is certainly not more than 1 to 1½ tons per acre, and is often much less.

As has been shown in the course of this section of my report, there is no need to go outside of India for good varieties, nor to other countries for good methods of cultivation. The best of varieties are met with; and the methods of cultivation in some parts are very perfect. What is wanted is the introduction of these good varieties and good methods into those parts, particularly the North-Western Provinces and Behar, which Provinces, it must be recollected, include much the largest area under cane of any Provinces of India.

CHAPTER VIII.

Agricultural Industries.

129. Under this heading Dr. Voelcker placed the discussion of such technical matters as the preparation of sugar, indigo, jute, etc. My investigations on the manufacture of sugar are so closely related to the experiments which have been commenced on the growth of sugarcane, that it appeared better not to divide the subject, but to deal with it entirely in one place, and hence the manufacture of sugar has been dealt in Chapter VII.

130. *Jute.*—The only other technical subject which I have had occasion to investigate is that of jute steeping.

This process, as carried out in Eastern Bengal, is the cause of much objectionable odours, and consequently the sanitary authority has tried to find a means of getting rid of the nuisance.

In 1895 I was instructed by the Bengal Agricultural Department to visit some of the centres of jute cultivation at the time when the crop was being steeped, in order to ascertain whether I could suggest any means by which the nuisance named could be overcome. Accordingly in August 1895 I visited Narainganj, Serajganj, and Jalpaiguri, and at each place saw the steeping and stripping or beating of the fibre, and a copy of my report on the subject was forwarded under my endorsement No. 186, dated 19th September 1895. At the time of my visit there was *no* objectionable odour, and it was therefore clear to me that the odours were *not* due to the steeping at all. On enquiry I then found that the odours were said to occur at a later period, when the land was drying up.

Briefly the circumstances of the case are these. The crop is grown with the aid of considerable amounts of water. Sometimes, as at Narainganj, the crop stands in several feet of water, at other places, as at Serajganj, on almost dry land. But in all cases for the purpose of steeping, deep water, whether in tanks or in streams appears to be immaterial, is *required*, and the bundles of plant are submerged for some days. For the actual stripping and washing process it is probable that but little water is necessary, but this point becomes practically of no great moment.

The main consideration is this. The weight of the crop is very great. I have seen no statements of what this actually comes to, but it is certainly some tons per acre, and it will be clear that it is out of the question for cultivators to carry the crop to some place at a distance from where it is grown, which might possibly be provided, in order to get rid of the nuisance which later on occurs. And, for a like reason, it is out of the question for him to remove the *steeped* plant to some such place. I do not think that the *steeping* has anything to do with the nuisance. The latter doubtless arises from the debris which is separated from the stems during the *stripping* process, and which later on, as the waters subside, decay. It appeared to me in short that, so long as the fibre has to be prepared by steeping in water, it will be possible to prevent this debris from being deposited at or near the fields, and consequently the odours will become generated as the land dries up, and I was therefore unable to offer any practical suggestions to remedy the evil.

CHAPTER IX.

PRACTICAL ENQUIRY.

131. The first thing necessary for the initiation and execution of useful agricultural work is the aid of a really qualified person to *direct* it.

In India each of the large Provinces has a department styled "Land Records and Agriculture," but it is admitted that up to the present most of these departments have done very little agricultural work, because of the want of qualified men in them.

At the Agricultural Conference of 1890 the opinion was expressed that "the Director of the Department should be provided with an assistant or assistants, who are experts in the practice and theory of agriculture," and that "it will be necessary to train natives . . . for the post . . . in this country" (page 72 of 1890 Conference).

In paragraph 410 of his report Dr. Voelcker expresses a similar opinion. He says:—

"Without attempting to lay down a rule to be followed in all cases alike, I would indicate my opinion that they should by preference be natives, and natives trained in India, not in England,"

and as to the number of such assistants Dr. Voelcker says (page 309):—

"This must vary in different Provinces, and according to the work done, but one for each division would probably not be more than would eventually be found useful."

At the Conference in 1893, when this subject was again brought up for discussion—

"It was generally agreed that, at any rate in the larger Provinces which could afford it, and in which agricultural enquiry and experiment were especially needed, there should be, unless and until native experts are available, at least one European expert highly trained in practical and scientific agriculture."

Finally this opinion has been endorsed by the Government of India in Resolution 5, dated 20th March 1897.

132. I may now properly express the opinion regarding this question at which I have arrived after a five years' sojourn in India. I have come to precisely the same opinion as that expressed by the 1893 Conference.

What is admittedly required is not only an agricultural expert, but a *Director* of the Agricultural Work. It has been admitted that the Director of the Department of Land Records and Agriculture is not generally qualified to initiate and control the agricultural work, and consequently this duty *must* devolve on some one else, whether he be styled "Assistant Director" or "Deputy Director," or anything else.

It will be hopeless to try the plan of employing several second-rate men in a Province in place of one good one. This was indeed suggested at one of the recent conferences which I attended. Such a class of man may be perfectly well able to execute simple duties which are all set out for him in a plain A,B,C manner. But by himself he would be useless.

Agriculture is just as much a technical subject as, (if not more so than,) the laying of railways and canals, or the management and control of forests. And just as it is necessary to employ highly qualified men to carry out these projects, so will it be necessary to employ some really good agriculturists to help in the improvement of Indian agriculture.

I have met and worked with a number of native agriculturists, and it has been a matter of great regret to me that in no case have they appeared to me to be qualified to *direct* the work of an entire Province. Some of them have been, and are doing most useful work, and as *assistants* can, I feel sure, be relied upon to execute details, but I doubt if more than this could have been expected of them.

Still, so far as this question of the nationality of the principal agricultural expert in any Province is concerned, it must not be forgotten that the Agricultural Programme has been generally of such an undecided character, that I think it likely the better educated natives have held aloof from entering upon

this sort of work as a means of livelihood. Again another thing must not be forgotten, and that is that we cannot expect to get *experts* direct from an Agricultural College! We only get agricultural *students* from such an institution, who may be trained to become experts in the course of a few years. And has not this in itself militated against those few who have been employed in Agricultural Departments? Is it not the fact that they have generally been placed in a department, the head of which has been quite incapable of training these students to become experts in agriculture? It seems to me possible that when more *active* Agricultural Departments are created, natives may eventually be found who are qualified to fill the post of principal expert.

133. In the second place, I wish to refer to a point in connection with the qualifications of this officer. He is styled "agricultural expert." But it will be found in practice that he will not be an expert in everything, even agricultural. One will be found to have a particular weakness for, and knowledge of, cattle, another will have studied particularly crops, whilst a third may have a natural liking for mechanics and have studied agricultural machinery especially. These natural peculiarities with men are not to be cast aside as of no consequence. If the present intention of Government be carried into effect, and European agriculturists be appointed as the chief experts in the several Provincial Departments, this diversity in qualifications will in all probability be met with. Among the several native agriculturists whom I have met, I have found a similar trait; one I know of who has a natural bent for machinery, another has a corresponding weakness for crops.

In such cases, the only way to do is to acknowledge the particular "weakness" and give the man every opportunity of developing it. A man will always do better work in his own particular line than in some other which is forced upon him.

134. Thirdly, I wish to go a step further, and pass to a consideration of what help is likely to be required by the chief agricultural expert. Some few junior assistants he is sure to require. But we must go further than this.

Taking, for example, a subject which is referred to in the Government of India Resolution, March 1897, namely, the more perfect preservation of the cattle urine in the stalls. We know without any further enquiry that in most parts of India there is much need for improvement in the ryots' practice. A year's experiment at the Cawnpore Farm has shown, that the greater part of this manure may be secured by keeping a little loose dry earth in the stall. Now in such a case as this, how is the lesson to be brought to the cultivator? Similarly in the case of ravine lands, we know how they may be cured and converted into productive lands; we also know that capital may be profitably invested in this manner. Indeed, this information is now some years old, and yet very few even among those interested in ravine lands know anything of what has been done. Only recently, when on tour, I met with several managers of Court of Wards' Estates who knew practically nothing about this subject, and in no case had they information of the methods employed at the Allahabad Grass Farm, where very considerable areas of ravines have been converted into level grass lands at the small cost of R20 per acre, nor had they visited the reclamation works at Etawah. It is useless *merely* to write accounts of these and similar experiments. In some respects these are exceptional cases. If, for example, one were to take up the study of some particular crop, several years might be profitably devoted to a mere enquiry into the varieties cultivated, and which are the better among them.

But however we look at the matter, the conclusion is readily arrived at that, within a comparatively short space of time, we shall be in a position to say "so and so would be an advantage to the ryot." It will be of little use to put such practical information in the Agricultural Ledger or other volume, and say "there that is done, and we will go on to something else." The end of such a procedure would simply be that for all practical purposes the Agricultural Department might not be in existence at all!

The question is, how is the "expert agency" to bring such information to the cultivator's door? It is a matter about which I have thought a good deal, and with which I should have been brought face to face had I (for instance) been able to prosecute further the sugarcane experiments in the North-Western Provinces and Oudh. With respect to this particular crop, the investigations had shown me that, not only are the varieties commonly grown in these Provinces for sugar production inferior, but that the system of cultivation is bad, and it would (probably) have been useless to simply distribute cuttings of a better variety of cane, for the latter would have required a better cultivation. Moreover, for the simple distribution of seed to the cultivator, an agency, much more extensive than any Agricultural Department is likely to be, would be necessary. What I should have done in the particular case of sugarcane would have been to solicit help from some of the Managers of Court of Wards' Estates who I knew could help; probably some few native gentlemen might have been found willing to act in a like capacity; but at the best the agency would have been a limited one.

135. What is really wanted is to persuade the large landholders to take an interest in agriculture as they have done in Europe. On them does not devolve the execution of all the details. But their *co-operation* is required. Their financial assistance renders the formation of Agricultural Societies possible. These societies provide a means by which the seedsman, the cattle-breeder, the implement-maker, can exhibit his wares to the farmer; and they employ the experts. Again, since the European landholder has taken up agriculture, they have employed thoroughly qualified *agriculturists* to manage their estates, and thus it comes about that there is a large demand for men who have these qualifications. If then the Agricultural Chemist, or the Engineer, or the cattle-breeder has an "improvement" to offer, there is an agricultural community of very considerable dimensions to whom he can show it; he is not at all dependent on a few.

In India, on the other hand, the landholder generally cares nothing about agriculture. His whole education has been foreign to the subject. And in such circumstances it is not surprising that he doesn't employ an agriculturist as his manager (when he requires one). The very small demand which exists for trained agriculturists is a further result; and finally if an Agricultural Department *has* anything in the way of an improvement to offer, there is no agency large enough to carry it into effect.

Doubtless, these are facts which have occurred to others besides myself. It may be that the case has presented itself as a difficulty too great to be overcome. But is it not a difficulty which *must* be overcome in order to carry agricultural work to a practical issue?

Here and there Agricultural Societies have been started. I have met with one or two which have existed for some years, and glanced through their Annual Reports. But it is perfectly certain that they require more efficient expert assistance than they have at present, and their attempts at field experiments are failures. Very probably such agricultural bodies would not under any circumstances be a success in this generation. But they might help to carry out both simple questions of enquiry and simple operations of improvement. For instance, I know of a case where a Collector was materially aided in such a way by native gentlemen. However, it seems to me that one *must* in the future look for aid in agricultural work outside the limits of the Agricultural Departments, and that aid can only be obtained by educating a portion of the richer classes to take an intelligent interest in agriculture.

It is a question of education, and I have referred to it in somewhat greater detail in Chapter XI of this report.

CHAPTER X.

Experimental Farms.

136. There were in 1893 experimental farms at the following places:—at Kirkee (Poona) in the Deccan, Nagpore in the Central Provinces, Cawnpore in the North-Western Provinces, Dumraon in Behar, Burdwan and Sibpur in Bengal.

I received instructions to visit the Cawnpore Farm early in 1893, but my first visits of inspection to the other farms were deferred until early in 1894. Since then, in accordance with the instructions contained in letter No. 700—8-7, dated 24th May 1895, from the Secretary to the Government of India, Revenue and Agricultural Department, I have inspected them whenever my tours brought me within a short distance of any of them.

Brief details of the various experiments which were in operation at these farms in 1890 are to be found in Chapter 18 of Dr. Voelcker's report; in the subsequent paragraphs of the present chapter I give details of the work which was in progress at the time I first inspected them, and of such experiments as have been subsequently instituted. Although at most of these farms the list included the comparative growth of varieties of crops, the trial of implements, the distribution of seed, and in some cases cattle breeding, attention was in the main paid to experiments on different *manures*.

Thus at Cawnpore there was the "Standard" series, including 52 plots on which manures were tested for wheat and maize, the "green manure" series of 19 plots for wheat, the dungs of different animals for maize (8 plots), pure chemical manures for wheat (6 plots), and 6 other experiments on the manuring of different crops, which included 36 plots. On the other hand, the following experiments with varieties of crops were in progress: 16 varieties of cotton, of which 1 was a local North-Western Provinces variety, 5 were from other parts of India, and the remaining 10 from America; 4 varieties of sugarcane, all from North-Western Provinces districts; 1 variety of *juar*; 2 varieties of maize, 1 of which was American; 12 varieties of wheat, 1 of which was from the North-Western Provinces; 4 from other parts of India and the remaining 7 from Australia and Canada; 8 varieties of barley, 4 of which were Indian and 4 were Canadian; 6 varieties of oats, all of which were foreign. In addition to these, there were 4 experiments on different methods of cultivation.

At the Dumraon Farm there were three experiments with manures which included 15 plots; of varieties of crops, three wheats were being tested. There was one experiment on ploughing for rice.

At the Burdwan Farm there were 4 experiments on the manuring of rice, jute, potatoes and sugarcane, including 35 plots; of varieties of crops, there were 2 of sugarcane, 1 of which was a Bengal and the other a North-Western Provinces variety; and 2 varieties of paddy. There were also 2 experiments in methods of cultivation.

At Sibpur there were 2 experiments on manuring crops. The varieties of crops which were being tested included the following: 5 varieties of sugarcane, 3 being from Bengal and 2 from other parts of India; 3 varieties of oats, all of which were foreign; 3 varieties of fodders, all of which were foreign; 10 varieties of tobacco, 2 of which appear to be of Bengal; 3 from other parts of India and the rest from abroad. Two experiments were being made on methods of cultivation.

At Nagpore there were 12 experiments to test the value of different manures for crops which included 49 plots. Of varieties of crops there were 6 of cotton, 3 being of the Central Provinces, 1 from Gujarat and 2 American; 2 varieties of linseed, both of the Central Provinces. There were in addition 9 experiments relating to methods of cultivation.

At Poona there were no experiments on manuring in progress; attention being directed principally to trials of various crops, and the encouragement of modern dairying.

137. I have gone into this list of experiments somewhat in detail in order to illustrate in particular two points. *First*, it will be seen that the greater part of the work consisted in the testing of manures for different crops, and *secondly*, that although the comparative growth of varieties of different crops had not been lost sight of, the work had been anything but systematic, and the varieties which were already in the hands of the cultivators of the districts in the neighbourhood of the farms had been almost entirely ignored. The farms had been, in fact, laid out for all practical purposes on exactly the same plan as those in England, such as those at Rothamsted and Woburn and elsewhere, for the testing of manures, whilst the two very necessary factors, "continuity" and "exactitude", had in some cases received far too little attention.

Investigations into the comparative quality of the crops of the districts in which the farms were placed had, excepting in the case of the Poona Farm, been practically omitted, and such varieties of certain crops as had been heard of as growing in other parts of India or in other quarters of the globe, were obtained, and given a place in the farm's programme. Now there can be no great objection to the testing of exotic varieties of crops, if a thorough knowledge of those locally grown has been gained, if it has been determined what their weaknesses may be, such as relatively small outturn, liability to disease, or low value in the market, etc., but it is manifestly of importance that this information shall first have been gained, else with what shall we compare the newly imported crops? Yet it may be unhesitatingly said that in no case has this procedure been followed. I make no apology when I admit that for some time after my arrival in India, I considered the experiments with manures for certain crops to be of major importance, and thought less of comparing varieties. The experience which I have gradually gained has led me to believe that such careful investigations into the qualities of the indigenous crops, as I above indicate, would prove of at least as much value as experiments on the value of different manures. It was indeed only when I commenced my investigations on the sugarcane crop that the fact forced itself prominently upon me; and if, as I have reason to believe, similar variations in the qualities of other crops exist, there cannot be any doubt that a very extensive field of useful work remains practically unexplored. Moreover, that such experiments with varieties of crops would prove of immense value, becomes evident from the fact that the two Bengal farms have actually been the means of introducing several new varieties of crops, including potatoes, jute, wheat, and sugarcane, into the neighbouring villages, and this description of work only requires to be amplified in order to confer on the cultivators generally an immense boon.

But as I have said, it is essential that the work should proceed methodically, and that the varieties locally grown should also be studied.

As an illustration of the manner in which a good knowledge of the varieties of any crop may be gained, the case of sugarcane may be taken. The importance of obtaining such information in regard to this crop has been dealt with in Chapter VII, and had I had the necessary time, I should have carried out the investigation in the following manner: firstly, information would have been obtained through Managers of Court of Wards' Estates, Zemindars, and possibly passed students of the Agricultural Schools, as to the names and certain characters of the cane crops in their districts. This information would have enabled one to judge of about how many varieties are grown and where they are principally situated. This part of the work has already been completed in a great measure by Mr. Mollison for the Bombay Presidency, and it has been commenced in the North-Western Provinces and Oudh. I should have then visited as many of those districts as possible, in which the principal varieties are cultivated, for it is likely that in some cases varieties which go under different names are identical. Moreover, it is of great importance that the circumstances under which the Assami grows different varieties should be understood. Some varieties are said to grow well on low-lying land, others on higher and drier land; some are said to be readily attacked by jackals and pigs, whilst others are said to be too hard. All such information should be obtained personally, if one can possibly visit the districts oneself.

Finally, when a thorough knowledge of the different varieties of the Province has thus been gained, and the conditions under which they are grown are thoroughly understood, the most promising might have been grown experimentally at the farm, and the chemical investigations completed.

Such a piece of work on the comparative value of any one crop may appear to be very great. It is, however, in my opinion *necessary*, and had the time which has been devoted at some of the farms to the somewhat spasmodic growth of exotic crops, been utilised in some such manner as that indicated, to the examination of indigenous crops, one would have been in a better position to judge of their qualities than is actually the case.

158. I would not be here misunderstood to suggest that I entertain doubts as to the value of the experiments on manures which have been in progress for some years or which have been more recently commenced at the farms. I consider them to be useful, especially for two reasons, *firstly*, if they are carefully carried on, a very fair approximation will be obtained as to the amount of certain plant food, such as nitrogen and phosphoric acid, which may be economically applied to certain crops; and *secondly*, whether one manurial substance containing a certain amount of plant food will produce an equal, a greater or a less quantity of the crop, than another manure containing a similar quantity of plant food. In all the newly-instituted experiments on manures these points have been particularly kept in view, and the manures applied as nearly as possible in proportion to the amount of plant food which they contain.

As to the comparative value of the plant food in different manures, the experiments at Poona on manuring sugarcane, for instance, indicate that the nitrogen in cattle dung does not produce as much, in the first year or two at least, as the nitrogen in some other manures, such as poudrette or certain oil-cakes. And again there are one or two instances on record that certain materials may be objectionable as manures; bassia cake, for example, proved absolutely fatal in one case to the sugarcane crop, although it has not again acted in this manner, and at Cawnpore this year there was some evidence in one instance that castor cake had been harmful to potatoes. These latter are singular cases, and it may be that the effects which have been attributed to the materials noted should more properly be referred to some other cause not at present known.

139. In making recommendations regarding any of these farms, I have adhered generally to the principle that to suggest any alterations either in the sites or the experiments unnecessarily would be a mistake, seeing that my tenure of office was to be for only a short period (actually for 4 years after the date on which I first visited most of the farms), and that it would be preferable to retain a site or an experiment which, although not altogether what I might myself have wished, might nevertheless be productive of useful information.

Thus in the case of the farms, the only one which appeared to me to be utterly worthless for field experiments was that at Sibpur.

The one at Dumraon consisted of a very stiff clay, the outturns of the crops had been uniformly low, and I suggested that, if a new site could be provided, an advantage would accrue, but that the old farm should be kept on for the time being. This suggestion met with a ready response at the hands of the Dewan of the Raj, and a new piece of land was placed at the disposal of the Agricultural Department the same year. This was sown with a crop of barley during the cold weather of 1894-95 and a plan of experiments drawn up and instituted in 1895. The experiments at the old farm were discontinued in 1896.

To the site of the Burdwan Farm there were some objections, the principal one being that it is liable to flooding in the rains, but judging by the results of previous experiments, it seemed to me that it would be a mistake to interfere with it at the time, and I recommended that it should be continued until a better site was made available.

The site of the Nagpore Farm is at first sight a good one, and I did not recommend any change in it either on the occasion of my first visit or

subsequently. I may say, however, that I have since come to the conclusion that for exact field experiments, more especially those in which the manurial effect of various materials is tested, it is anything but suitable. The results of some of the experiments are not at all regular, and since I have no reason to doubt the care which is bestowed upon them by the Superintendent, Mr. Joshi, who is indeed a most painstaking and capable man, one must conclude that for some reason or other the site is not suitable for much of the work which has been attempted. On the other hand, it answers the purpose of a School Farm well enough, and is thus an advantage to the students of the Agricultural School which is also there situated; it is probably fairly well suited to the growing of different varieties of crops, (provided of course the past treatment of certain plots is borne in mind,) and for testing methods of cultivation or implements.

The farm at Kirkee, Poona, was found, prior to my first visit, to be wholly unsuited to exact field experiments with manures, and has been kept solely for growing varieties of crops. Another area, 8 miles from Poona, was taken up early in 1894 for sugarcane experiments, and this has proved itself well suited to the purpose.

Finally, the site of the Cawnpore Farm is well suited to field experiments of almost any nature.

140. Similarly, in the case of the experiments with manures, I found some which it seemed to me might be advantageously left alone, although they were not altogether free from criticism. Thus, for example, two experiments at Burdwan, one for the rice crop and another for jute, appeared to be giving fairly uniform results; and in the case of the "Standard" series at Cawnpore, in which manures are tested for the wheat and maize crops, it seemed undesirable to alter it at the time, although it was open to objection in some particulars. In such cases I left the experiment unaltered.

141. But in those experiments on manures which have been planned during my tenure of office, I have adhered to two principles. *Firstly*, that the experiments should test the *comparative value* of the manurial materials, and to this end they have been applied by preference *singly*, and mixtures of manures have been avoided as far as possible. *Secondly*, that the experiments should determine what amount of these materials may be applied to certain crops so as to obtain a maximum outturn without any unnecessary waste. Moreover, I have in some cases been able to provide for distinct relationship between experiments on the same subject at several of the farms. Thus, for the sugarcane crops, the manures are applied at Cawnpore, Dumraon, and Burdwan in such quantities as shall supply 250 lbs. or 500 lbs. of nitrogen per acre, and in the experiments at Poona one series of plots receives an application of 500 lbs. nitrogen per acre. In the case of potatoes, a simple relation likewise exists between the amounts of manure applied at the three farms first named. The materials are moreover in many cases alike, and the experiments become therefore more or less comparable between the farms.

The issues involved thus become in each case extremely simple, and valuable information regarding the requirements of some of the Indian crops will be supplied.

In this connection paragraph 460 of Dr. Voelcker's report may be suitably quoted—

"One great advantage of having all experimental work under the general survey of a "scientific adviser" is that by this means the same experiment may be concurrently tried over different parts of India. In this way general truths may be obtained for the whole country instead of for one particular spot only. A uniform result would be of far more lasting and wide-reaching benefit than more numerous ones which might be the outcome of the peculiar circumstances of special districts. I would much rather see a joint conclusion of this kind arrived at as the result of experimental work on farms than the many and often conflicting conclusions which are now drawn."

142. In addition to experiments on the value of manurial materials and varieties of crops, the several methods of cultivating sugarcane have been added to the list.

The testing of implements at the farms has, as more fully explained in the chapter devoted to that subject, not received the attention which it

deserves. Too much cannot, however, be expected of "one pair of hands." The staff employed is generally very limited indeed, but what is wanting in a still greater degree is the mechanical training which would, if present with the staff, make itself felt in more directions than one, and infuse life into this part of the work. When one recollects that the chain pump has been made at Cawnpore for short lifts for upwards of 20 years, and that during the whole time no really reliable set of tests have been made on the work performed by such native implements as the swing basket or the *dhenkli*, the competitors, so to speak, of the chain pump, it must be admitted that a very desirable piece of work has still to be done; and similarly when we find implements of acknowledged value, like the hand centrifugal sugar separator, standing idle in a show yard or even left in a godown unused, instead of being exhibited in a business-like manner, it becomes clear that there is a lack of energy somewhere.

I do not wish to appear too critical of the work of the subordinates in the Agricultural Departments, because, as pointed out elsewhere, more is expected of them in some cases than should be. It cannot be seriously suggested for a moment that these departments are properly manned, and if therefore a certain part of the work is creditably performed, these officers will have done as much as can be reasonably expected of them, and the rest must wait until more assistance is provided.

143. *General management of the farms.*—The Bombay Farms are superintended by Mr. Mollison, Deputy Director of Agriculture, who devotes not only very much time to them, but also infuses his own spirit of enthusiasm into his subordinates.

The Farm at Nagpore is in the immediate charge of a Superintendent who has not only received a good agricultural education at Poona, but who has put that education to very good use. Mr. Joshi exhibits considerable originality of thought in the management of the farm, and takes very great interest in looking after the various details of the arrangements. He resides on the spot.

At Cawnpore I found the supervision to be in need of improvement, and in 1895 the farm was placed in the immediate charge of Mr. Subbiah, the Principal of the Agricultural School. This officer, like Mr. Joshi, has put his agricultural studies to very practical use; he throws a thorough interest into the details of management, and the farm is well looked after. He also resides at the farm.

The two farms in Bengal are still managed in the same manner as at the time of Dr. Voelcker's visit and which he criticises in paragraph 444 of his report. They are each in charge of the Assistant Directors, and the execution of the details is attended to by a resident overseer. I was obliged to offer similar criticisms of the very cursory supervision given to them by the Assistant Directors in 1894, on the occasion of my first visiting them. The Director concurred in my remarks, and since then the farms have been visited more frequently by the Assistant Directors in whose charge they are severally placed. But the system as a whole is capable of improvement. Dr. Voelcker wrote—"Such occasional supervision is of little practical value, especially when, as in the instance under notice, the resident Manager was a man of very ordinary calibre and had other estates to look after and other duties to perform." Owing to the loss of a crop in the dry weather of 1895 under circumstances which I believed to have been avoidable, I again addressed the Director on this subject of supervision. These overseers are not qualified to work alone for months together, and I urged that one at least of the Assistant Directors should have his office at one of the farms, preferably at Dumraon. The Director concurred in my view, but as one of the Assistant Directors was then on sick leave (and remained incapacitated for some time), it was not at the time possible to carry it out. I still adhere, however, to the opinion I then expressed. One cannot do agricultural work by sitting month by month in Writers' Buildings. The difference between the way in which the work is done in the Bombay Presidency and in Bengal is most marked; in the former the Deputy Director is constantly on tour and at the farms, and inspires his Assistants with his own zeal, and this is what is required elsewhere.

144. *Farm Records and Reports.*—The recording of the results of

experiments made at the several farms, and the publication of them in a form readily understandable to the outside public, was a subject referred to by Dr. Voelcker in his report, and the matter was likewise discussed at the Agricultural Conference held at Simla in 1890 (page 11).

145. *Farm Records.*—In paragraph 467 of Dr. Voelcker's report, the importance of keeping careful note at the farms of the various circumstances relating to the experiments, such as mode of cultivation, treatment of plots, etc., as likewise of any peculiar meteorological features of the season, attacks of insects or other special occurrences which might influence the course of the experiments, is urged. This matter has latterly received more attention at the farms than formerly. Such a procedure will naturally be followed without the need of any special instructions by those who take any real interest in the experiments in their charge.

146. *Farm Reports.*—The published reports of experiments is dealt with by Dr. Voelcker in paragraphs 468 and 469 of his report, and he points to the necessity of this being done in such a manner, that the subject-matter may be readily appreciated by those interested. In 1894 I was instructed to submit a note on the subject of these Farm Reports generally. The recommendations which I then made were briefly as follows, and were submitted to the Local Governments under cover of Circular No. 6—33-2, dated 22nd April 1895 :—

(1) That the records or results of experiments should be published (in the case of any one farm) in some uniform manner. The report should be divided into chapters each relating to some one subject which should remain intact from year to year.

(2) That in adopting a certain arrangement care should be taken that it should be a *good one.* As an example of what I consider a bad arrangement, the case was quoted of experiments on using the iron plough, experiments on manuring, and experiments on the varieties of a certain crop (rice), being all included under one chapter; the following chapter being devoted to a similar list of experiments in which wheat was the crop grown. It was pointed out how, that if any one happened to be interesting in iron ploughs, he would naturally turn to the chapter on *implements* and not to that on either rice or wheat, for his information.

A list of useful "Heads of subject-matter" was added, which included "Implements," "Methods of cultivation," "Manures" (of whatever sort and for whatever crop), "Varieties of crops," "Distribution of seed," "Fungi-cides," etc.

(3) That in reporting the details regarding experiments, a simple and uniform order might advantageously be adhered to, that the question submitted to experiments should be concisely, but clearly, stated in the first place; then should follow the procedure, *e.g.*, when the experiment was instituted, the cultivation given to the land, date of sowing, kind and amount of manure applied, date of harvest, etc., or if any alterations have been made in the experiment since its institution. That the *manner* of reporting the results obtained, such as outturn, should be *uniformly* adhered to, and that, in the case of any experiment which is being carried out over a series of years, the results obtained in previous years should be included; that averages should not be struck until *uniform* results have been obtained over a number of years; that it would be a great advantage to *record* all areas in terms of square yards or acres, and weights in pounds avoirdupois, and to *publish* results in terms of pounds per acre.

(4) That it is a mistake to try to apply money values to the individual yearly results of any experiment which is known beforehand *must* be continued over a series of years before any definite answer to a question can be expected.

(5) That great care should be exercised in the criticising the results of experiments, otherwise wrong conclusions might readily be deduced. It is always far better to say, "no reason can at present be assigned for such and such an erratic result" than to try to imagine one.

(6) That the number of appendices, which it had been customary to place at the end of some reports, might advantageously be much reduced or omitted altogether. It must be remembered that, if a report has been drawn up under some simple arrangement and the results clearly set out, there would be no need of appendices.

(7) That a brief history of the farm, with a rough plan, and a short description of the meteorology of the year, might properly find a place at the commencement of the report.

These recommendations have been generally adopted at the farms, and I think it will be conceded that it is at least possible now to readily find out what experiments are being made on any particular subject.

The Poona Farm.

147. At Poona there are two experimental areas, one for the growth of varieties of crops and fodders and for the dairy, the other for the growth of sugarcane.

I visited Poona on the following dates, the time being principally devoted to the sugarcane experiments: November, 1st to 27th, December, 4th and 5th, and 16th to 31st, 1893; January, 1st to 6th, and February, 2nd to 6th, 1894; January, 28th, to February, 24th, 1895; March, 2nd to 28th, 1896; December, 22nd to 26th, 1896; January, 15th and 16th, 1897.

The Sugarcane Experiments.—Early in 1894 Mr. Ozanne, Director of Land Records and Agriculture, requested me to plan out, in consultation with Mr. Mollison, Deputy Director of Agriculture, a series of experiments on the manuring of sugarcane. This crop is cultivated in the neighbourhood of Poona, probably better than anywhere else in India, with the exception of, may be, Bengal, and it is not unusual for cultivators to get an outturn of 8,000 lbs. of *gur* (raw sugar) per acre.

Accordingly a piece of land in the sugarcane-growing country near Poona, was selected; it is fairly level and appeared to be well suited to the purpose, and the three years' experience gained with it has proved it to be so. It has an area of about 13½ acres, about ¼ of which is occupied by roads and pathways. Samples of the soil of this field were taken before the commencement of the experiment in 1894, and again in 1897, and have been analysed. These are referred to in paragraph 150. The principal question which Mr. Ozanne originally put in regard to the sugarcane crop, was whether the cultivators were using unnecessarily large quantities of manure? Such a question in relation to any Department of Indian Agriculture may seem at first sight curious, when it is recollected that the acknowledged chief want of the Indian cultivator is a large supply of manure than he usually possesses. Mr. Ozanne's knowledge of, not only Indian, but of European agriculture, however, enabled him to perceive that the question was not necessarily superfluous. The cultivators apply enormous quantities of manure for this crop; as much as 50 tons per acre of poudrette being not at all uncommon. Such an amount of manure supplies about ten times as much plant food as a very heavy crop of cane can take out, and hence it will be evident that the question originally proposed is a sound one. Owing to the large demand, the price of manurial materials is very high, and if the experiments at Poona should demonstrate that a smaller amount of manure than that commonly provided, will produce a full crop, they will be the means of enabling the people to economise somewhat. The larger number of plots is devoted to this question of the amount of manure necessary, and a number of different materials are used in varying proportions. But in addition it is sought to gain information regarding several other questions related to the cultivation of this crop. These include how much irrigation water is required, and how often should it be put out? Should the manures be applied entirely at the time of planting, or should a portion be "top dressed", when the crop has established itself? How long can one profitably "ratoon" cane? At what period of growth should cane be harvested in order to obtain the highest yield of sugar?

148. (*a*) *The comparative manure series.*—In 1894-95 and 1895-96 this

series included 15 plots of $\frac{1}{5}$ acre each. In 1896 the area was extended and 12 plots added.

It was known that cultivators employed several materials as manure for this crop; poudrette, cattle manure, and castor cake being the principal ones. The demand for these manures had risen considerably, and it appeared very desirable that other materials, especially the refuse oil-cakes, should be included in the scheme of experiments, in order to determine whether some of them could not find a place in this market, and so prevent too great a rise in price of the first-named manures.

Touching this point I will here quote from Mr. Mollison's Report on the Poona Farm for 1894-95 (page 29, paragraphs 14 and 15) :—

"There is no definite relationship between the value of the manures as determined by chemical analysis and their actual commercial value. The price of a manure should chiefly depend upon the percentage of nitrogen, potash, and phosphoric acid, and the condition in which these constituents exist. Organic matter present in a high percentage, as in cattle dung, would of course add appreciably to the value of the manure. It is certain that the cane cultivators of the Poona District, though they are much over average in intelligence, fail to recognise the differences in manurial value of the manures they use. In support of this, I note the fact that castor cake has doubled in price in the Poona District during the last three years; whilst poudrette (against the use of which there is no prejudice) has not risen appreciably in value. The chemical analysis of these manures would indicate that castor cake in comparison with poudrette is exceedingly dear. This fact becomes the more anomalous when it is known that poudrette is perhaps four times dearer at Poona than at any other populous centre of the Presidency. At Surat the town manure, consisting largely of night-soil, is worth 8 to 12 annas per cart-load as compared with ₹3 at Poona. The Surat poudrette is not strictly comparable with that at Poona, because it is manufactured in a different manner; but at both places it is readily bought by Kunbis for the extensively irrigated crops of the neighbourhood, and at both places castor cake is also largely employed. The price of castor cake cannot differ to any great extent between districts; castors are widely cultivated and the cost of transporting the cake by rail a considerable distance is not great. Poudrette is dear in Poona because of the keen demand for it. Yet dear though it is, the men who buy it at ₹3 a cart-load and cart it four to eight miles often make the dung of their cattle into fuel cakes to be sold in Poona. The inference is that cattle dung at Poona is worth as fuel a better price than as manure; the manure, if well decayed, being worth at best ₹4 per ton. Bones in the Poona District have trebled in value during the past three years, owing entirely to the extrinsic circumstance that there is a keen demand for export.

"There are several edible oil cakes now used for feeding cattle in India, and largely exported, which can be bought in Poona at a considerably cheaper rate per ton than the castor cake and *Karanj* (*Pongamia glabra*) cake now so extensively employed as manure. Dr. Leather's analysis proves that the edible cakes contain much higher percentages of nitrogen (the most valuable constituent of manures) than the manure cakes, and in our extended scheme of comparative manure experiments started in the current season, the value of the edible cakes as manure is being tested.

"I had no hesitation in proposing this trial, because these edible oil cakes are either exported and thus lost to the country or they are chiefly fed to milch cattle in large towns. The solid and liquid excrement of these cattle is not used as manure. The urine drains away somehow, whilst the dung is sold (in Bombay, for instance, at 8 annas a cart-load) to be converted into cow dung cakes and burnt as fuel.".

Regarding the oil cakes as manures, Mr. Mollison, in paragraphs 11 to 13, page 34, of Farm Report, 1895-96, after pointing out the importance of the nitrogen being in a readily available condition, expresses the opinion that the oil-cake by the country mill is more readily decomposed in the soil than the hydraulic pressed cakes. He says:—

"Oil-cakes as made in Europe are generally considered to be slow in action as manure. Oil-cake, as made in the ordinary Indian *ghani*, is extremely quick in its action.

"In India oil-seed, as ordinarily pressed, is ground up into an impalpable powder as the oil is expressed. The oil-cake is consolidated during the process, but before it is applied as manure it is again powdered, and I have no doubt the minute particles of cake will, when they come into contact with the moisture of the soil, again disintegrate into impalpable powder. It is easy to understand that a manure in such a fine state of division will very soon show its effects upon a crop. The method of preparing cake in Europe and in the hydraulic press mills in Bombay is quite different. The seed is crushed, but not into fine particles. The crushed seed is cooked or steamed, thus the oil escapes freely from the oil cells. The cooking of the crushed seed would, of necessity, convert the albuminoids into a much more insoluble condition than as they exist naturally. The albuminoids contain nearly all the nitrogen of the seed; therefore it is reasonable to suppose that the nitrogen, as it exists in

hydraulic pressed oil-cake does not become available as plant food nearly so soon as that in oil-cake made in the ordinary country *ghani*.

"Hydraulic pressed castor cake as made in Bombay is held by the market gardeners to be poor stuff as manure. At Bassein they have tried it. It costs in Bombay ₹22 per ton. They prefer to use castor cake madein Gujarat, which costs in Gujarat 80 lbs. per rupee, or say, ₹30 per ton. In our extendeds cheme of experiments in the current season we are trying the one cake against the other."

Then, again, it was considered desirable that bones (raw and dissolved) should also find a place among the manures employed. The continued export of bones from India has been condemned by some as occasioning a serious drain of valuable fertilising substance from the Empire.

The seriousness or otherwise of this question is dealt with in paragraph 50, Chapter I, of this report. In this place it need only be said that it seemed desirable to include bones in the list of manures for sugarcane, for the same reason as they have been applied in some of the other experiments, namely, in order to see if crops can be found in India to respond to their action, in the same manner as some crops, such as root crops and pastures, have been benefited by them in Europe.

Lastly, saltpetre is employed on certain of the bone-manured plots in order to augment the supply of nitrogen.

149. It became necessary, when drawing up this scheme, to refer all the manures to one common standard, and the standard adopted was the nitrogen content of the manures. The amounts of phosphoric acid could be likewise determined in them, and as it was clear that the amount of this plant food would certainly vary considerably in the several materials, its value would be indirectly determined.

The following statement sets forth the amounts of nitrogen applied to different plots. The phosphoric acid will vary each year for each plot, but the lowest amount will be about 300 lbs. per acre in the case of certain oil-cakes and the largest will amount to about 800 lbs. in the case of the bones.

	lb of nitrogen per acre.
Poudrette	1,000, 600, 500, 400, 250
Cattle dung	500
Farm-yard manure	600, 500, 400
Fish manure	500
Castor cake (steam-pressed)	600, 500, 400
,, (country-made)	600, 500, 400
Karanj cake (*pongamia glabra*)	500
Mauha cake (*bassia latifolia*)	500
Cotton-seed cake	500
Safflower cake	600, 500, 400
,, and earthnut cake	500
Bone meal	130
,, superphosphate	130
,, meal (130), saltpetre (120)	250
,, superphosphate (130), saltpetre (120)	250

150. As already mentioned, samples of the soil of this experimental field were taken prior to the commencement of the experiments, and again in 1897, *i.e.*, after three applications of manure had been given and three crops removed. The following statements Nos. 21 and 22 embody the analyses. Unfortunately the samples were not taken from the same plots on both occasions, and it has therefore been assumed that the soil of plots 4, 7, and 12, which have been analysed in 1897, had, in 1894, the same composition as that of the nearest lying plot which was sampled in that year.

STATEMENT No. 21.

(*a*) *Samples taken in 1894 before commencement of the experiments.*

	Plots 2 and 3.	Plots 5 and 6.	Plots 8 and 9.	Plots 13 and 14.	Plot 22.
Total nitrogen	·014	·034	·031	·024	·035
Total phosphoric acid	·031	·025	·014	·022	·016
Readily available phosphoric acid	·010	·010	·005	·008	·010
Available potash	·008	·008	·005	·009	·016

(*b*) *Samples taken in 1897 after three applications of manure.*

	Plot No. 4.			Plot No. 14.			Plot 7.	Plot No. 8.		Plot 12.
	1″—12″.	12″—27″.	27″—34″.	1″—12″.	12″—24″.	24″—33′	1″—16″.	1″—10″.	10″—19″.	1″—16″.
Total nitrogen . . .	·041	·032	·015	·057	·045	·010	·047	·054	·039	·043
Total phosphoric acid . . .	·066	·034	·077	·045	·046	·087	·110	·038	·026	·085
Readily available phosphoric acid .	·020	·017	·007	·011	·007	·017	·016	·010	·006	·011
Available potash	·012	·008	·002	·010	·008	·010	·008	·003	·003	·012

It will be observed that there has been in the case of both total nitrogen and total and available phosphoric acid a very material increase to the soil on all the plots examined. For comparison with plot No. 4 one may take the mean of the analyses (of 1894) of the neighbouring plots Nos. 2 and 3 and 5-6. For comparison with plot No. 7 the mean of the analyses (1894) of plots 5-6 and 8-9; and for plot 12 the analysis (1894) of plots 13-14. The amount of available potash, on the other hand, has remained almost unaltered.

An interesting question in relation to these experiments is, whether any notable amount of the nitrogen, which is admittedly being applied in much larger quantity than the crops can extract, is passing away from the soil in the drainage waters.

Such a calculation may be made from the analyses, and statement No. 22 embodies the results. The weight of soil per acre to a depth of two feet has been taken as 8,000,000lbs., which, although deduced from weighments of black soil taken at another place (Nagpore), will not be very far from the truth. The amount of nitrogen removed by the crop has been deduced from the weight of the crops from the several plots, together with the analyses of the sugarcane crop as published in Agricultural Ledger No. 19 of 1896. It may be that these amounts are not altogether correct, but they are in any case small when compared with the nitrogen originally in the soil and that which has been added in the manure.

STATEMENT No. 22.

Showing loss or gain of nitrogen *in Manjri soils to depth of 2 feet (assumed to weigh 8,000,000 lbs. of soil per acre).*

	Plot 4, Bones.	Plot 14, Cattle Manure.	Plot 7, Fish Manure.	Plot 8, Castor cake.	Plot 12, Poudrette.
Nitrogen, original . .	·024 per cent.	·024 per cent.	·032 per cent.	·031 per cent.	·024 per cent.
„ lb per acre . .	1,920 lb	1,920 lb	2,560 lb	2,480 lb	1,920 lb
„ applied . .	680	1,800	1,600	1,462	1,847
TOTAL .	2,600	3,720	4,160	3,942	3,767
Extracted in crop . .	130	150	280	260	260
Finally 1897 . . .	·036 per cent.	·051 per cent.	·047 per cent.	·047 per cent.	·043 per cent.
Equal to lb per acre . .	2,880 lb	4,080 lb	3,760 lb	3,760 lb	3440 lb

These figures indicate that up to the present there has been no very serious loss of this valuable plant food.

151. (*b*) Regarding the other questions which are also subjected to experiment, those relating to the best time for applying the manure, and the most economical amount of irrigation water to be used, are particularly interesting. For the former, six plots of cane are employed, farm-yard manure, poudrette and castor cake being applied each on one plot, (1) entirely before planting, (2) in part before planting, in part during the early stages of growth. The amount of irrigation water employed for this crop is very considerable, amounting altogether to upwards of 100 inches, and since the total depth of soil on this field

varies only between 16 inches and 3 feet on many of the plots, before the soft rock called *Murrum* is reached, it has been feared that a good deal of nitrogen is liable to be carried off in the drainage water. The estimated amount of nitrogen, as detailed in statement No. 22, indicates that of the total nitrogen supplied in the manure, no large amount has up to the present been so lost. But that a considerable proportion of this nitrogen is not readily available is certain, and if one could determine (which is unfortunately not possible in the present state of our knowledge) the amount of readily or immediately "available" nitrogen, it might be found that of *this*, some part *is* lost. However, the solution of this question must be relegated to future experimental enquiry, and in the meantime these top-dressing experiments may indicate whether such losses are sustained, and whether a smaller amount of manure will be sufficient if applied in portions during the growth of the crop.

The experiment on the most economical amount of water to be applied is carried out with a similar object, namely, to endeavour to reduce the present usual quantity, which approaches 100 inches. On one plot $\frac{3}{4}$, and on another $\frac{1}{2}$ of the normal supply is given. In the first year the best yield was obtained from the use of $\frac{1}{2}$ the usual supply, and the second year from the plot receiving $\frac{3}{4}$ the usual allowance, and a similar result was obtained in the third year. Doubtless the most economical amount of irrigation water will vary somewhat with the season, but so far as they have gone, the experiments would indicate that a saving of irrigation water may be effected.

The Cawnpore Farm.

152. Owing to the fact that I could, without loss of much time, generally call at Cawnpore when passing to and from Dehra on my various tours, I have been able to inspect this farm more frequently than the others. I inspected it on the following dates: April 1893, and 11th to 13th August 1893; 12th to 14th September, 6th to 17th November, 25th to 27th December, 1894; 7th to 13th January, 23rd April, and 31st August 1895; 17th January, 8th to 17th February and 8th April, 1896; 20th to 31st January and 8th to 11th April, 1897; and I submitted notes and recommendations regarding the experiments in progress on the following dates: May 1893, 6th August 1894, 21st February 1896, 25th February 1897.

153. Regarding this farm I cannot do better than quote Dr. Voelcker's opinion of it, in which I entirely concur:—

"It is a well-conducted experimental station in a convenient position and with a suitable soil; and although faults in detail may be found with it, the general conception and working of it are thoroughly good" (paragraph 478, page 359).

154. *Management.*—The farm was under the control of the Assistant Director until 1895, when it was placed in the immediate charge of Mr. Subbiah, the Principal of the Agricultural School. There is, of course, a Farm Superintendent under him, who sees to the execution of details. Until recently this officer has generally been a man who had not received any particular agricultural education, but one of the passed students from the school now holds this office, and I feel sure that, although his work consists merely in carrying out details, it will be done in a more intelligent manner, and the farm will generally benefit in consequence. The experiments have recently been executed with considerable care, and the results, which are published in the Annual Report, may, I feel sure, be generally relied upon.

I will now allude to the experiments in brief detail.

155. *Experiments with manures.—The "Standard" series.*—The experiment consists in the testing of a number of manures on the wheat and maize crops, and was instituted in 1880 by Mr. Fuller. Several manures were excluded and several others added in 1883, since which time it has remained undisturbed. There are four sets of 13 plots each, and in each set of plots the manurial treatment is the same; one plot of each set, for example, receiving annually the same weight of cattle dung, a second of each set the same weight of dung and bone dust, etc. On one set of plots wheat is annually grown, on a second set the crop is always maize. On the other two sets of plots a rotation of wheat and maize is maintained and one set of plots bears wheat in the same year that the other set bears maize. These latter have been designated the "duplicate" sets. In the case of these "duplicate" plots the wheat crop follows maize after a fallow of about 13 months, whilst maize follows wheat

after an interval of about 3 months. The list of manures includes the following: the weights are per acre; cattle dung 180 maunds (containing about 100 lbs. nitrogen); cattle dung 180 maunds and bone dust 4½ maunds (containing about 100 lbs. nitrogen); cattle dung 180 maunds and gypsum 3 maunds (containing about 100 lbs. nitrogen); sheep dung 180 maunds (containing about 140 lbs. nitrogen); sheep dung 180 maunds and bone dust 4½ maunds (containing about 140 lbs. nitrogen); sheep dung 180 maunds and gypsum 3 maunds (containing about 140 lbs. nitrogen); poudrette 180 maunds (containing about 95 lbs. nitrogen); saltpetre 3 maunds (containing about 25 lbs. nitrogen); saltpetre 3 maunds and bone dust 4½ maunds (containing about 35 lbs. nitrogen); saltpetre 3 maunds and bone superphosphate 3 maunds (containing about 35 lbs. nitrogen); ashes of 180 maunds of cattle dung (containing practically no nitrogen); ashes of 180 maunds of cattle dung and saltpetre 3 maunds (containing about 25 lbs. nitrogen); and lastly the thirteenth plot of each series has no manure.

The plan of this experiment is good in many respects. Like the similar experiments at Woburn and Rothamsted in England, it has shown how important it is to apply a nitrogenous manure to wheat; it has likewise shown that a similar truth holds good in the case of maize. Secondly, it has been brought out that one can grow both wheat and maize uninterruptedly on the same land, either with or without manure, for a long series of years. Up to the present there has been no diminution of outturn on the manured plots. Thirdly, that with such allowance of manure as those employed, an average wheat crop of over 1,500 lbs. (about 25 bushels) and one of about 1,200 lbs. of maize may be obtained annually. Further, by means of the "duplicate" set of plots, the effect of the longer period of fallow preceding the wheat crop and the shorter period of fallow preceding the maize crop is brought out. It would also appear certain that the amount of poudrette which has been applied is unnecessarily large for the wheat crop.

On the other hand, the plan might have advantageously contained simpler manures. For example, I would not have applied mixtures of dung and gypsum or dung and bones. Also it would have been better to apply such quantities of the manures as would supply definite amounts of nitrogen or phosphoric acid. This condition, however, could not be complied with at the commencement of the experiment, since there was then no means of getting the materials analysed.

156. *The Green Manure Series.*—Another experiment which was instituted prior to 1893 was what has been called the "Green Manure" Series. On a series of plots certain crops were grown, cut down in the immature state, and ploughed in as a manure for the wheat crop. Thus indigo and hemp were utilised in this manner in one case, each crop by itself, and on a second plot some gypsum was added at the time of ploughing. But the experiment included the trial of other materials. Thus fresh and old indigo refuse (seet), and the water from indigo vats and from steeping hemp, were applied on four other plots. These are not strictly "Green manures." Thirdly, wheat was grown after indigo, hemp and lucerne crops had been removed. A "No manure" plot was included. In addition, some parts of the experiment were checked by treating plots similarly for the wheat crop at other parts of the farm.

This experiment, then, did not entirely consist in ploughing in green crops, but included the testing of other questions besides. But the general idea of the experiment was good, and although I suggested the alterations about to be noted, it seemed advisable to leave some parts of it undisturbed. The "applications" which seemed well worth continued trial were the following: indigo and hemp crops ploughed in; fresh and old "seed" manure; lucerne, hemp, and indigo crops preceding the wheat. On the other hand, there is no reason to suppose that the addition of gypsum to the indigo or hemp at the time of ploughing in these crops would produce any benefit. Gypsum has found a place at this farm as an adjunct to other manures, such as dung, because it was thought that the property it possesses of absorbing ammonia would prevent the escape of this valuable constituent from the soil during the process of the decomposition of the nitrogenous organic matter. A little consideration will show of how little consequence the application of gypsum in such field experiments can have. In the first place, the amount of free ammonia in ordinary agricultural soils at any

time is quite small, it being rapidly converted into nitric acid. Secondly, the soil itself is such a good absorbent of ammonia (as proved by the late Dr. Voelcker's experiments many years ago) that it would prevent any ammonia which is present in the soil from becoming dissipated. Thirdly, the amount of gypsum applied was so trivial that, when ploughed in to a depth of 5 or 6 inches, it would not amount to much more than ·01 per 100 parts of soil. I therefore recommended the discontinuance of this part of the experiment (2 plots). Then the application of the refuse water from indigo vats and from hemp steeping was open to objection. At the time when I first examined these experiments, I concluded more from the figures of outturn, which showed no advantage from the treatment, than from anything else, that these refuse liquors could hardly have any valuable fertilising matters in them. As a matter of fact, I have since seen excellent effects at indigo factories produced on succeeding cereal crops from running the waste water from the vats on to adjacent fields. The quantity applied in such cases is, however, very considerable. But so far as this experiment is particularly concerned, it is to be recollected that testing the value of the application of any particular watery liquid to plots as manure, is not a very simple experiment. Strictly speaking, the same volume of pure water should be applied to a neighbouring plot, otherwise one plot will have had an irrigation which the " no manure " plot has not received. I recommended that this part of the experiment should likewise be stopped. Thus what remained of the experiment consisted of the following :—

(*a*) Green crops ploughed in ; indigo and hemp.

(*b*) Fresh and old indigo " seet " as manure.

(*c*) Wheat following leguminous crops ; indigo and hemp cut green, and wheat sown immediately every year ; lucerne grown on two plots in alternate years in the cold weather, and a crop of wheat taken from one of these plots each year.

Sir Edward Buck recommended that the number of " green manures " should be increased if possible, and *khurti*, *urd* and rape were added to this section (*a*) of the experiment. Under section (*c*) there were added the following: wheat alternating with *urd*, *arhar*, and gram.

The tabulation of the results of this experiment in the Annual Report has not been quite so clear as might be wished, and I have suggested that they should in future be set out in sections, similar to those now indicated. It will then become more apparent that the experiment consists, in reality, of three essentially different parts.

Another section has recently been added to the experiments on the value of leguminous crops in enriching the soil for crops of other natural orders.

157. In the sections of the experiment just described, the value of ploughing in certain leguminosæ, and the effect of the " crop residue " of plants of this order, are being tested.

The third question, what is the value of a leguminous plant when grown *with* one of another natural order, had not been included. Owing to the very common practice which prevails with the ryots of growing such mixtures of crops as those alluded to, this question is, for India, one of very great significance.

It has been proved by European chemists that the *papilionaceæ* assimilate atmospheric nitrogen. That nitrogen enters into the composition of the plant, and at its death forms food material for succeeding plants which grow on the same or neighbouring ground.

But the very common practice of the Indian cultivator is to grow these crops *with* those of other natural orders, such as cereals and millets, and the question naturally arises, are the *papilionaceæ* able to assist in any way the plant of another natural order *which is growing alongside them ?* It is perhaps doubtful whether this question can be satisfactorily answered by means of field experiments. One difficulty which presents itself at the outset is this.

If one wishes to compare two or more fields of the same crop, they must be grown under, as nearly as possible, the same conditions in all respects, excepting

the one varying item which forms the subject of experiment. Thus if we wish to test the value of manures, we vary the experiment in this one respect only, *i.e.*, the same crop is grown, the same description of cultivation is given, the same amount of irrigation, and same weight of seed per acre, etc., and if varieties of crops are being tested, the treatment of the land must be the same for all the varieties in every respect. In the other parts of this experiment (sections *a* and *c*), for instance, the land can be prepared for the wheat crop of the "No manure" plot and on those on which leguminous crops have been grown, in the same manner, the same amount of cultivation can be given and the two plots thus placed under like conditions in all respects, excepting in that one, namely, the previous growth of a leguminous crop.

But if one grows, say, gram with wheat in order to determine whether the gram assists the wheat in any way, say, by the assimilation of atmospheric nitrogen, the difficulty is to grow wheat on a neighbouring plot *under similar conditions but without the gram.* On the plot *with* gram, this crop occupies some of the ground, some space to tiller in, some of the surrounding atmosphere, Consequently, if the *same number* of wheat plants are grown on the next plot *without gram,* these will manifestly have advantages of soil and atmosphere. over the wheat which is growing with the gram. On the other hand, supposing we grow as many wheat plants on this "no gram" plot as there are of gram and wheat plants on the "with gram" plot, this wheat is still under different conditions to its neighbour, for the gram is a small low-lying plant, whilst the wheat plants, which have taken its place in the assumed "no gram" plot, is erect and the conditions as regards atmosphere and soil are still unequal.

What one would like, of course, would be, to grow such a plant on the "no gram" plot with the wheat, as would occupy the same ground as the gram and possess the same habits of growth, but *not* have the power of assimilating atmospheric nitrogen; but such a plant would be very difficult to find.

It was on account of these difficulties, and the feeling that field experiments might consequently lead to erroneous conclusions, that I hesitated for a long time to propose definitely any such field experiment for execution at the farms. It is indeed probable that this question cannot satisfactorily be answered in this way, and that recourse must be had to "pot cultures." For the latter there has been, however, no opportunity whatever, neither the time nor the assistance necessary being available.

158. What I have proposed to be commenced at the Cawnpore Farm is the following: if it should prove possible to get concordant results there, it might be well to start similar experiments elsewhere. Taking a plot of as uniform a nature as possible, it is proposed to divide it lengthwise into three parts. On the centre portion a leguminous plant and one of another natural order are to be sown, by means of a "drill," in alternate rows; a record is kept of the weight of seed used of each crop. On the land on one side of this an equal weight of the non-leguminous crop is sown in rows as far apart as on the centre ("with leguminous") plot; on the third plot, double the weight of the non-leguminous crop is to be sown in double the number of rows as on the other two.

The crops to be experimented upon in the first instance are: (1) gram and wheat, (2) *arhar* and *juar*, (3) *arhar* and cotton.

159. *Manures for the sugarcane crop.*—In connection with the experiment on sugarcane at several of the farms, a series was instituted at Cawnpore in 1894. In the first instance, only small amounts of manure were used, but after I had been able to compare the results obtained at Poona with those at Cawnpore, it appeared probable that the manuring employed at Cawnpore was insufficient to obtain a good crop, and the experiment was reorganised in 1896 and brought into more strict comparison with those at the other farms. It now includes the following manurial applications:—

Cattle dung (3 plots) at rates equal to 125, 250 and 500 lbs. nitrogen per acre.

Poudrette (2 plots), at rates equal to 250 and 500lbs nitrogen per acre.

Castor-cake (2 plots), at 250 and 500 lbs. nitrogen per acre.

Saltpetre and bone dust (1 plot) at 125 lbs. nitrogen per acre (in each material).

Saltpetre and bone superphosphate (1 plot) at 125 lbs. nitrogen per acre (in each material.)

There is one "no manure" plot.

The area of the plots is $\frac{1}{4}$ acre in one set and $\frac{1}{5}$ acre in the other. When the sugarcane experiments were first commenced, it was thought that a crop could be taken off the same land *each* year, but it soon became evident that this was impracticable, and when the series above detailed was decided upon, two pieces of land were taken up to be employed in alternate years.

At Poona there are likewise two sets of plots for similar alternate treatment, but in each case a second ("ratooned") crop of cane is taken in the second year, and the land is then allowed to lie fallow. At the Bengal farms only one crop of cane is to be taken from a set of plots, and the land then fallowed for a year.

At Cawnpore it was decided to adopt a somewhat different procedure. It is known that a very heavy crop of cane will not take up more than about 100 lbs. of nitrogen or phosphoric acid per acre, and many crops much less. Consequently there should be a considerable "manure residue" on most of the plots, and in order to try to utilise this, a crop of potatoes is to be taken without any additional manure from the sugarcane plots at Cawnpore after the sugarcane has been removed. Experience alone can decide whether this is a wise course to pursue, but if it proves to be so, it must be recollected that the plots will in all probability be "levelled" down, so to speak, in the manurial sense, and the following crop of cane will start with less of the "manure residue" left by the preceding cane crop, than is the case at the other farms.

160. *Manures for the potato crop.*—Experiments on the value of different manurial materials for the potato crop have been made at the Cawnpore and the Bengal Farms at different times, but they lacked system. Those at Cawnpore were simplified in 1893, but after analysing the manures it was found that they still needed to be put upon a more uniform basis.

Moreover, I wished, if possible, to determine how much manure is necessary to yield a good crop. It is known to be capable of yielding a good return for large quantities of manure, and it was arranged that two varieties should be grown at this farm with different manures at a rate corresponding to 100 and 200lbs. nitrogen per acre respectively. This amount was larger than I should have been disposed to think necessary, but Mr. Subbiah, whose knowledge of the ryots' customs is considerable, pointed out that both poudrette and cattle dung are regularly employed by the better cultivators in quantities approximating to the higher of the above rates, and the experiment has been commenced on this basis. It will be seen, however, that if after a few years the outturn of the crop from the smaller amounts of manure approximates to that from the larger, and thus indicates that the larger amounts are more than sufficient, the quantities can readily be reduced, say to one-half, and applications at rates of 50 and 100 lbs. nitrogen per acre respectively employed.

As explained in a former paragraph (138), the object of these experiments with manures is not only to compare the relative effects of different materials on certain crops, but also to determine what amounts may be economically applied, and if these experiments for the potato crop are carried out on the lines suggested, they will eventually answer this purpose.

161. *Varieties of crops* —The comparative cultivation of varieties of different crops has generally formed the subject of experiment at this farm. As indicated in an earlier paragraph (137), the experiments with varieties have, in my opinion, been frequently lacking in one particular; instead of making a systematic collection of the varieties of certain crops of the North-Western Provinces and Oudh, and carefully studying them, attention has centred principally on varieties of crops from other Provinces or countries.

Thus in the case of cotton, there were 9 American varieties, 6 varieties from other Provinces and 1 local variety. Of 12 varieties of wheat, 7 were Australian and Canadian, 4 were from other Indian Provinces and only 1 North-Western Provinces variety, and excepting sugarcane, the same applies to all other crops experimented on. Of course in the case of cotton the desire

to introduce American varieties is readily understood, but still considering the importance of the subject and the length of time over which this matter has been the subject of discussion, more information might have been gained regarding those varieties grown in the North-Western Provinces and Oudh.

Then, too, there was practically no system about this part of the work. The outturn was recorded, but no attempt seems to have been made to come to a definite conclusion as to which were the best varieties, and which could be left out of the experiment, and in the case of cotton, whilst the fibre was at first submitted to experts for valuation, this practice was again given up.

In the case of varieties of cotton, they were again submitted to an expert in 1893, and 4 of them, which had not shown much prospect of being better than some of the better Indian varieties, were excluded from the experiment and only the remaining 5 are now grown.

162. Varieties of sugarcane have been grown systematically since 1894. One variety was brought from Poona, but the remaining 5 varieties are all from North-Western Provinces Districts. As I have explained in a previous paragraph, this is the only crop which I have examined critically. From the rough survey which I made during the cold weather of 1896-97, it seems probable that there are between 20 and 30 distinct varieties of this crop in the North-Western Provinces, of which only 6 have been at all carefully experimented with at the farm. Regarding the directions which these experiments have taken, reference may be had to Chapter VII.

163. *Other crops.*—Among varieties of other crops which have been cultivated at this farm are wheat, oats, *bajri* and some fodder crops such as *juar*, maize and *guar*. Some of these are useful, as for instance the large variety of *bajri* (*Pennisetum typhoideum*) from Gujarat. But the remarks already made regarding the comparative investigation of local varieties applies equally here.

It is of course impossible to examine all crops at once; they could only be taken in hand singly.

Methods of Cultivation.

164. *Early and late sowing.*—Under this section, experiments have been made at Cawnpore on the value of early sowing of maize and cotton by the aid of artificial irrigation, and it has been shown that in the majority of years an increased outturn in the case of both these crops is obtained by this means; but it is also probable that the ultimate outturn much depends on the weather at the time of flowering.

165. *Comparative value of new and old indigo seed.*—At the request of Mr. Wishart, an experiment was commenced in 1893 on the comparative value of new and old indigo seed.

Seed of 4 months, 1 year and 4 months, 2 years and 4 months, 3 years and 4 years, old respectively, was sown, and the yield of (*a*) green plant, (*b*) seed, determined.

The experiment was repeated three times and the results were very fairly uniform. It was found that the seed which was 1 year and 4 months old produced the heaviest yield of plant; that which was quite new (only 4 months old) produced nearly as much, but the older seed produced less.

Of indigo seed, the highest yield was obtained in the first year from the plant of the "16 months old" seed, in the second year the highest yield was obtained from the newest seed, but the yield from the plant of the "16 months old" seed practically equalled it. The yield from the older seed was less. Thus the conclusion may be safely drawn that indigo seed a year old is more serviceable than either younger or older seeds.

166. *Implements.*—I have explained in an earlier paragraph (142) that trials of implements, although usually included as a part of the programme of work at the farms, has not been carried out very exhaustively.

167. *Ploughs.*—A comparative experiment is annually made at Cawnpore with the iron plough, and it is found that the tilth required for wheat is obtained with half the labour when the iron plough is used, as when the wooden one is

employed. There is some evidence that the cultivators are beginning to use this implement, for one or two hundred are annually sold.

168. *Seed-drills.*—In 1895 I recommended that the wooden seed-drill, which is commonly employed for many crops in the Central Provinces, the Deccan, and some parts of the Madras Presidency, should be tried at Cawnpore, and two have been obtained. Practice is necessary in order to employ this implement properly, but there can be little doubt that for many crops it is a great advantage. The plants have a more uniform space to grow in, and the weeding can be done by bullock power.

169. The following analyses of the surface soil of certain of the experimental plots at this Farm will be of interest to those who study the effects of manuring.

STATEMENT No. 23.

Analyses of Soil from Cawnpore Experimental Farm.

	Total nitrogen.	Total phosphoric acid. P_2O_5	Available phosphoric acid. P_2O_5	Available potash. K_2O.
	Per cent.	Per cent.	Per cent.	Per cent.
Unmanured plots.				
Rabi standard No. 11	·024	·085	·021	·012
Kharif standard No. 13	·016	·053	·022	·007
Alternate series A. No. 13	·017	·088	·030	·007
Ditto B. No. 11	·023	·071	·014	·012
"Green manure" series No. 5	·017	·052	·015	·027
Manured plots.				
Rabi standard No. 3 (Each manured annually with 180 maunds or 14,400 lbs. of cattle dung per acre.)	·031	·069	·032	·012
Kharif standard No. 3	·065	·094	·047	·027
Alternate series A. No. 6	·024	·072	·036	·012
Ditto B. No. 3	·042	·072	·025	·019
"Green manure" series No. 2 (manured annually with 120 maunds or 9,600 lbs. per acre of fresh indigo seet).	·038	·089	·009	·011
"Green manure" series No. 1 (manured annually with 120 maunds or 9,600 lbs. per acre of old indigo seet).	·107	·079	·008	·007

THE NAGPORE FARM.

170. I visited the Nagpore Farm on the following dates: 11th to 19th March 1894, 28th August to 2nd September 1894, 25th and 26th January 1895, and 28th February to 2nd March 1896, and I submitted notes on the work of the Farm on 26th September 1894 and 10th March 1896. Owing principally to the fact that I have had no opportunity of touring in the Central Provinces and consequently know very little of its agriculture, I have refrained from suggesting many new experiments at this Farm, and I thought it better to allow the experiments, which had been instituted by Mr. Fuller, to be continued.

171. *Management.*—The Farm is managed in a most capable manner by Mr. Joshi, the Superintendent, and, had it not been for the serious attacks of rust on the wheat crops, and of "talap" on the linseed, the experiments would have doubtless yielded more uniform results than has been the case.

172. *The "Ville" Series.*—The only experiments which have been recently instituted are the following. On a series of plots pure manurial materials

containing only certain plant foods, had been applied for wheat. Thus, on one plot potash and nitrogen but no phosphoric acid; on another, nitrogen and phosphoric acid but no potash; on a third, potash and phosphoric acid but no nitrogen; on a fourth, all three plant foods were supplied; on a fifth plot no plant food at all was given. Whilst I did not consider the experiment had any value from the practical standpoint, for the benefit of the students at the school it was of use. When the wheat was not seriously attacked by rust, it demonstrated to them which of the particular plant foods employed was most required by wheat. In 1894 I suggested that linseed might with advantage be substituted for wheat, and the experiment might then possibly teach something new, since we do not know as much about the requirements of the linseed crop as we do about wheat.

173. *Manures for oil-seeds.*—In 1896 I planned out a set of experiments to test the value of bones for certain oil-seeds.

It had been clearly demonstrated that no advantage occurred from their application to cereals, and the same appears to hold good in the case of sugarcane. Since the question of the value of bones as manure in India is constantly being raised and their export condemned, it seemed desirable to apply them to some other crops. The following experiment was accordingly instituted:—

Four series of five plots each were selected, and the following manures applied to one plot in each series:—

(1) No manure.

(2) Saltpetre containing 20lbs. nitrogen per acre.

(3) Burnt bone containing no nitrogen, but 100 lbs. phosphoric acid per acre.

(4) Raw bone containing x lbs. nitrogen and 100 lbs. phosphoric acid per acre.

(5) Raw bone containing x lbs. nitrogen and 100 lbs. phosphoric acid, and saltpetre containing 20 lbs. nitrogen per acre.

The four oil-seed crops experimented upon are linseed, mustard, til, and safflower. These crops are, moreover, not to be grown each year on the same series of plots; the series, on which the til and safflower are grown one year, will bear linseed and mustard in the following year, and *vice versâ*. This procedure appeared to be necessary owing to the difficulty experienced in growing some of the oil-seeds, more especially linseed (and probably til) on the same land continuously. Since the corresponding plots of each series are manured annually alike, there should be no objection to this system of rotation.

174. *Varieties of crops.*—A good deal of attention has always been paid at this farm to the growth of varieties of different crops, more especially of cotton and wheat.

Cotton.—Whilst one or two varieties of exotic cotton have generally found a place in the Farm's programme, three of the principal varieties cultivated in the provinces have always been grown as well, and in this respect the work is not open to the same criticism as that at some of the other farms. The American variety "Upland Georgian" has been grown for a number of years, and there was some likelihood at one time that the cultivators would take to it. But, although the staple is superior, the outturn is less than some of those generally grown, and the general conclusion arrived at is that the short-stapled "Jari" pays the cultivator better under present conditions of price and trade.

Wheat.—In the case of varieties of wheat, too, attention has centred principally on those belonging to the Provinces, and their comparative rust-resisting qualities have been observed.

175. The subjoined statement No. 24 exhibits the analyses of some samples of soil from this farm. The proportion of *total* nitrogen is slightly higher than that in most *regur* soils: so likewise is the proportion of *total* phosphoric acid. The proportion of available phosphoric acid varies. In the surface soil of plot A-4, which has been regularly manured, there is a very fair proportion, but

in the surface soil of plots A-8 and A-7 there is very much less. Plot A-8 has been regularly manured by ploughing in a green crop, but it must be recollected that this system of manuring adds no phosphoric acid to the soil, though one might have anticipated that this procedure would have occasioned an accommodation of *available* phosphoric acid. Plot A-7 has remained unmanured, and the low proportion of available phosphoric acid is readily understood.

The amount of available phosphoric acid in the sub-soil of all the plots is low.

The percentage of *available* potash is fair in all the samples.

STATEMENT No. 24.

Analysis of soils from the Nagpore Farm.

	Plot A-4, manured with 6 tons of cattle manure per acre per annum.		Plot A-8 manured with green hemp ploughed in annually.		Plot A-7 unmanured.	
	Surface soil.	Sub-soil.	Surface soil.	Sub-soil.	Surface soil.	Sub-soil.
Nitrogen (total) .	·065	·033	·045	·033	·050	·047
Phosphoric acid (available).	·020	·008	·008	·004	·007	·005
Phosphoric acid (total).	·093	·065	·078	·058	·064	·054
Potash (available).	·021	·010	·016	·010	·012	·010

THE BENGAL EXPERIMENTAL FARMS.

176. There were, at the time I took charge of my office, experimental farms at Sibpore (Calcutta), Burdwan and Dumraon.

Of these the one at Sibpore appeared to me to be wholly unsuited to exact field experiments, and I recommended its discontinuance.

The one at Burdwan, although not free from objections, seemed to be capable of yielding definite results from certain of the experiments.

At Dumraon there were two areas at which experiments were being carried out. One at village Bhojpore was not sufficiently uniform or level to form a suitable site, and, as it was not essential to the experiments, I suggested that all the experiments might with advantage be carried out at one place.

The other area at Dumraon consisted of a stiff clay, and I urged that another site should be selected, if possible. This view was adopted by the Director and the Dewan of the Raj, and the latter placed another piece of land of about 30 acres at the disposal of the department.

The three Bengal farms are fully described in the succeeding paragraphs.

General Management.—I may here refer to the general management of these farms. Each is in charge of one of the Assistant Directors of the Department, and the details of the work are carried out by a Resident Overseer. The latter is in each case what one would describe in England as a "Working Foreman" or bailiff and is not of the educational status of what would be understood as a "Farm Manager."

It was clear to me, as it had been to Dr. Voelcker, that the system of supervision was anything but sufficient to ensure exactitude in carrying out the experiments. Dr. Voelcker writes:—

"444. I found, however, in one case that the farm had only been visited once in the course of the year. Such occasional supervision is of little practical value, especially when, as in the instance under notice, the resident manager was a man of very ordinary calibre and had other estates to look after and other duties to perform."

I represented to the Director the importance of better supervision on the part of the Assistants in charge, and more frequent visits have been paid to the farms latterly than was formerly the case. There is still, however, in my opinion, room for improvement, and the experiments will not be free from certain suspicion of error until arrangements similar to those existing at Nagpore and Cawnpore are established. For example, only quite recently, a statement of results of some experiments on sugarcane were submitted to me from one of these farms, in which 84·5 per cent. of the juice expressed from sugarcane was reported, and in another case 77·6 per cent., and in yet a third 15·3 per cent. of gur. The first is wholly impossible, the second highly improbable, and the third impossible, if the gur had been made properly. If such figures were published, they would simply bring the farm and its management into justifiable ridicule.

But it is not merely that the experiments in progress at these farms require a more careful supervision at the hands of the Assistant Directors, but their presence is also very desirable in the district or districts in which these farms are situated. The reason why the Poona farms are of so much more practical value than most of the others in India is because the Deputy Director makes a point of getting a very clear insight into the varieties of crops grown by the cultivators in different parts of the Presidency, and the conditions under which they are grown. It has appeared to me for some time that these farms in India will prove of more value to the people if the experiments consist in the careful comparison of different varieties of crops, than in the comparison of manures, and, as a matter of fact, these Bengal farms have already been the means of introducing several new crops or varieties of crops to the cultivators of their neighbourhood. But a knowledge of the varieties at present grown by the people is as essential as that of testing varieties from other districts or provinces.

This intimate knowledge can, however, only be gained if the Assistant Directors spend a large part of their time on tour in the districts, and make a point of finding out the better classes of tenants, enlisting their sympathies with the work, and obtaining from them a knowledge of their various difficulties.

Then, again, in such a case as that of finding out a means of preserving the potato tubers for seed from one season until the next, it is useless to expect the overseer to be able to experiment on such a problem. He can carry out any instructions which may be given, but the thing wants watching from day to day through a season or, may be, longer. At present, the reason why one sort will keep perfectly well in heaps, whilst another is said to go rotten even when placed in simple layers, is not known; the atmospheric conditions which exist when the disease first manifests itself have not been noted, and many other points should be taken into consideration; new ideas would probably occur to the Assistant Director were he frequently on the spot to examine the tubers, and other experiments than those originally (empirically) started would suggest themselves. It is only in this manner that such a problem can be solved. That it is worth solving admits of no doubt, for the people are willing to pay as much as ₹5 per maund for Naini Tal seed potatoes.

Similarly in the case of implements, which have received generally far too small a share of attention in Bengal, if the Assistant Director lived among the people, he would be able to judge fairly exactly in what direction improvement would be possible; he would, as already indicated, meet here and there with ryots willing to see an implement tried, and, by giving reasons why such and such new implement was not suitable to the people, enable the Assistant Director to judge whether the reasons given were adequate or merely imaginary excuses.

In Bengal there is any quantity of irrigation from short depths, and yet the chain pump has not been properly and persistently demonstrated at either farm; nor has the centrifugal sugar separator, one of which has been in possession of the Department for years, been properly utilised, whilst, close to Dumraon, a trade worth lakhs of rupees per annum has sprung up solely owing to this machine.

177. But so long as the Assistant Directors spend nine-tenths of their time in Calcutta, such matters as these cannot find a place in the operations of the farms, for it is manifestly useless merely to write an instruction to a farm manager :—"Test the Cawnpore chain pump" or "try putting potatoes on shelves", for he is not qualified to test implements properly, nor to *devise* means of preserving potatoes.

Otherwise these farms have done well. They have been instrumental in providing the ryots with better potatoes, wheat, sugarcane, and jute, and this work only requires to be amplified in order to gain for them a very front rank among establishments of this nature.

I will now refer in greater detail to the farms and the experiments there in progress.

The Sibpore Farm.

178. I have only inspected this farm once, namely, on February 17th and 28th, 1894. On that occasion I examined not only the experiments, but the surface and sub-soil of different plots, and it was clear to me at once that this farm can never be usefully employed for field experiments of a reliable or exact nature.

Dr. Voelcker's remark about this farm (*vide* page 375 of his report) is as follows :—

"Inasmuch, however, as the land previously was jungle land, it is probably too rich, more especially in vegetable matter, for any manures to exercise an influence, until by constant cropping it has lost some of its excess fertility."

179. The opinion which I formed regarding this land is embodied in the following paragraphs of the inspection note which I submitted to the Director at the time :—

"In the absence of analysis, it is somewhat unsafe to form a definite conclusion, but judging by some of the experiments, it would seem that the soil is distinctly rich. It is, moreover, 'made land,' *i.e.*, land which has been levelled and filled in artificially. I examined it to a depth of about 4 feet in three different places, and broken bricks were present in all at various depths ; at the bottom of one hole there was a *pukka* brick floor."

"Regarding the situation, it is out of the reach of the general cultivating classes, and consequently, even if there were experiments which had proved successful in providing a definite result, it is not readily get-at-able by the cultivators. In neither the matter of situation nor of soil does this farm fulfil the conditions mentioned, and it would seem desirable to avoid any further expense on it."

180. Since then I have analysed three samples of soil from Sibpore, and the following statement embodies the results :—

Statement No. 25.

Analyses of the soil from three plots at the Sibpur Farm.

	A.	B.	C.
Insoluble silicates and sand	78·95	72·88	73·30
Soluble silicates	·03	·28	·28
Iron (Fe_2O_3)	4·73	6·28	6·36
Alumina (Al_2O_3)	4·47	7·96	7·93
Manganese (MnO)	·11	·12	·11
Lime (CaO)	2·07	2·03	1·52
Magnesia (MgO)	2·00	2·14	1·61
Alkalis (soda and potash)	·08	1·79	·64
Sulphuric acid (SO_3)	...	...	...
Phosphoric acid (P_2O_5)	·11	·12	·11
Carbonic acid (CO_2)	3·82	3·95	2·97
Organic matter and combined water	3·63	2·45	5·17
	100·00	100 00	100·00
Nitrogen (total)	·063	·065	·065

On the same occasion the Director submitted the further question to me—

"Whether, in the event of this farm being unsuitable for experiments, it would be well to establish a dairy with European machinery, etc.?"

and my reply to the question may also be quoted—

"It would be a very great advantage to have such a dairy near Calcutta, if only as an object lesson in cleanliness, and Government would do well to take an early opportunity of following the examples of Bombay and the North-Western Provinces and establish a dairy by preference near Calcutta. But the total area at Sibpore is only some 25 acres, and there is, I understand, no land anywhere near to provide grazing and exercise. If the latter could be provided, the land at Sibpore would provide fodder and the project might well be seriously considered. If the matter be taken up, a European expert should be employed for the first year or two, until a thoroughly reliable native manager has been trained."

181. *Management.*—In the matter of management, too, there was very much to be desired. The overseer, who was a Mohamedan, could speak and write Urdu, but could not speak either English or Bengali. Mr. Basu, the Assistant Director in charge, could speak and write English and Bengali and could speak Urdu but could not write it. Consequently all orders issued in writing by Mr. Basu had to be translated into Urdu before the overseer could carry them out.

182. *The Experiments.*—The experiments which had been attempted were generally without any definite plan, and practically nothing in the shape of definite results could be drawn from them.

But, whilst the system of management could have been remedied and the experiments put on a more practical basis, it was impossible to alter the land, and, on account both of its nature, as well as its non-agricultural surroundings, I had no hesitation at all in condemning it as wholly unsuited to the purpose. Varieties of crops might in some cases be grown there, but even in such a case there would ever be present the uncertainty occasioned by the uneven nature of the land.

Burdwan Farm.

183. I have inspected this farm five times, namely, 21st February 1894, 23rd January 1895, 13th August 1895, 8th January 1896, and 10th to 13th February 1897, and submitted a brief report to the Director on the work on each occasion.

184. *Site of Farm.*—Regarding the site of this farm, which is a narrow strip of loam, 18" deep, lying on almost pure sand, bordering on the Eden Canal, I pointed out in my first inspection note that it is not all that might be desired, since it appears to be liable to inundation in the rains.

Another defect which I only found out later, is that the soil contains very little phosphate. It is a singular thing that, whilst bone meal has not proved of much value as a manure on any of the other farms, it has caused considerable increases of outturn in the crops at this farm generally, and the explanation of this doubtless lies in the fact that the soil contains so little phosphates. Statement No. 26 exhibits the analyses of two samples of soil from this farm:—

Statement No. 26.

	Plot 8.	Plot 84.
Insoluble silicates and sand	83·97	85·76
Soluble silica ($Si O_2$)	·34	·35
Iron ($Fe_2 O_3$)	5·58	4·71
Alumina ($Al_2 O_3$)	6·09	6·43
Manganese (MnO)	·12	·09
Lime ($Ca O$)	·28	·22
Magnesia ($Mg O$)	·66	·58
Alkalis ($Na_2 O$, $K_2 O$)	·56	·50
Sulphuric acid ($S O_3$)	·02	...
Phosphoric acid ($P_2 O_5$)	·04	·03
Carbonic acid ($C O_2$)	·21	·16
Organic matter and combined water	2·13	1·17
	100·00	100·00
Nitrogen	·04	·04

Whilst I think a more suitable site might readily be found, I do not consider the above defects form a fatal drawback to the work. Useful experiments have been and still are being carried out there.

185. *Size of Plots.*—These were in some cases far too small, measuring as little as 2½ cottas (or ·04 acre). There was a little difficulty in remedying the defect, because(as already explained) I wished to cause as little alteration in those experiments, which were worth being continued, as might be. In the manure experiment for paddy, the smallest plot is about $\frac{1}{10}$ acre, in that for jute, there are three plots of a less area than $\frac{1}{10}$ acre. These were left without alteration, but the same experiment was commenced on another series of plots last year. For the sugarcane and potato experiments, which have been commenced or re-arranged during the time I have held office, the plots have been generally about $\frac{1}{12}$ acre in area. One of the chief difficulties met with in arranging for fair-sized plots at Burdwan, is that many parts of the land are liable to be submerged in the rains, and consequently the area, suitable for most experiments, is somewhat limited.

186. *Management.*—As pointed out, both by Dr. Voelcker in his report, (paragraph 444) and by myself in my inspection notes of this farm, there is still something wanting in the matter of supervision on the part of the Assistant Director in charge. It is now better than formerly, but I still hold the opinion that it should receive a visit from him once a fortnight. Burdwan is so close to Calcutta that a fortnightly visit cannot be said to be likely to cause very serious interruption in office work. The books in which the records are kept are well arranged and weighments are now made in pounds, instead of maunds, as formerly.

187. *Experiments with manures.*—The experiments include the following. The testing of manures for paddy which has remained unaltered, but another set of plots are to be now added to check the results obtained by the first series. The amount of manures applied in the first series have had no very definite relation to one another, and this defect will be remedied in the new series by applying them all at a rate corresponding to 25 lbs. of nitrogen per acre.

(2) A series of experiments on manuring the sugarcane crop was commenced in 1895, and bear a close relation to the corresponding experiments at Dumraon and Cawnpore, though those at Burdwan are of a more limited nature. They include only three manures, namely, cattle dung, bones and bone superphosphate, which are applied in amounts equivalent to 250 lbs. of nitrogen per acre. The series includes two sets of four plots each. Each plot measures $\frac{1}{12}$ acre.

(3) A series of experiments in manuring potatoes was likewise commenced in 1895 on six plots which include the manures, cattle dung, castor-cake, bone meal and bone superphosphate, as well as an unmanured plot, each plot (excepting the last named) receiving manure equal to 125 lbs. of nitrogen per acre.

(4) The jute experiment, which I found in progress when I first inspected this farm, had been yielding concordant results, and, although some of the plots were very small, I considered it better to leave it as it was. Another series of plots was taken up in 1895, on which the same experiment is to be made so as to check the results of the first set.

188. *Varieties of crops (1).*—The experiments with varieties of sugarcane were also re-organised in 1896 to bring them more into conformity with those at other farms.

Three varieties of the Burdwan District, together with a variety from Sibpore, were grown in 1896, and another has been added this year. Two plots are reserved for this purpose, and in order that the several varieties may be grown under like conditions of soil and manuring, one half-plot receives one manure (cattle dung) and the other half-plot a corresponding amount of another manure (castor-cake). The varieties are then grown side by side in long lines from one end to the other of the plot. The plots are employed in alternate years, as it is not possible to use the same plot annually for this crop. The plots are, it is true, too small, but that is occasioned by the nature of the land and is unavoidable.

(2) Only three varieties of potatoes are experimented upon, namely, the local sort, and that from Naini Tal, and a variety from Cherapunji; but the Naini Tal variety has been obtained from three different sources. They are all grown under like conditions of manuring; the plots measure $\frac{1}{1\frac{1}{2}}$ acre each, and the land is very well suited to the purpose.

189. *Methods of cultivation* (1).—Three methods of growing sugarcane have been tested for some years at this farm, namely, (*a*) that commonly practised in many parts of India, in which the land remains level and the plants are not earthed up at all; (*b*) the cane is planted in furrows and later on the plants are earthed up so as to form ridges; (*c*) the cane is planted in pits, three "sets" in each. Which of the two latter is the better practice, remains to be seen, for the third method has not had a sufficiently extended trial, but the experiments at all the farms show clearly that the method (*b*) is superior to the first, and as a matter of fact it is regularly practised by cultivators in the best sugarcane-growing districts, such as Burdwan and Poona. It requires to be *well* done, however, and not as I found it at several of the farms, where the ridges were barely a couple of inches high. The ridges, moreover, require to be earthed up several times during the period of growth, for the irrigation water washes them down a good deal each time.

(2) Three series of experiments to test the question whether potatoes are more economically planted as whole tubers, or as "cut sets", were started in 1895 on six plots, each $\frac{1}{1\frac{1}{2}}$ acre in area. Each plot receives an equal quantity of manure (castor-cake).

(*a*) 15 maunds of potatoes (per acre) are cut up and planted as "sets" in one plot and the same *number* of whole potatoes are planted in the contiguous plot.

(*b*) The same weight (15 maunds) of cut "sets" and whole tubers are sown in a pair of plots.

(*c*) 15 maunds of whole tubers are sown in one plot and the same number of cut sets planted in the neighbouring plot.

The difference between (*a*) and (*c*) is then simply that a larger weight of whole potatoes and cut sets is sown in (*a*) than in (*c*). It will be observed that the same weight, and (approximately) the same number of cut sets are planted in (*a*) and in (*b*), whilst (*c*) has a smaller weight of cut sets; and the same weight and (approximately) the same number of whole tubers are planted in (*b*) and in (*c*) whilst (*a*) has a larger weight of tubers. If the experiment be continued for 3 or 4 years, a definite answer to the question should be obtained.

(3) Another matter in relation to the cultivation of sugarcane has been recently taken up, namely, whether it is better to plant cane from the top ends only, as is the general practice in the Burdwan District, or to cut up the whole cane for "sets", which is the more common practice in India. This subject I have explained at length in a former paragraph (No. 118). As there explained, since there is little doubt that the top ends of the cane contain less sugar than the main part of the stem, it is, *ceteris paribus*, an economy in sugar to utilise top ends only for propagation, rather than to cut up the main part of the stem for this purpose. Why cane should be so generally propagated from the main stems, if the tops will do as well, is not clear. It may be that some varieties deteriorate by being propagated in this manner; the evidence obtained of the *Samsara* points to the conclusion that cane does *not* so deteriorate.

190. *Implements.*—Trials of implements have not been taken up at this farm quite as extensively as might have been. The iron plough has been tested regularly against the wooden one, but the hand centrifugal sugar separator might well be experimented with, for the people generally make "rab" at Burdwan, and it has to go to the bazar in ghurras which are easily broken. If "turbine" sugar, and the solid gur from the molasses, were made, they would be packed more easily and cheaply, besides producing a better price for the articles.

So likewise the chain pump and the Baldeo lift might be exhibited to cultivators in Burdwan, as there is a great deal of irrigation from short depths. In the distribution of seed this farm has done perhaps more than any other, for it has been the means of introducing better potatoes and jute, which latter is apparently a new crop in the district.

Dumraon Farms.

191. I inspected the farms at Damraon five times, namely, 22nd and 23rd February 1894, 14th January 1895, 30th August 1895, 9th January to 14th 1896, 1st to 6th and 19th February 1897, and submitted a report to the Director on each occasion.

192. *Site of Farms.*—At the time of my first visit to Dumraon, there were two pieces of land, one near Dumraon and the other at village Bhojpore, which constituted the Dumraon farms. The small area at Bhojpore could not seriously be considered an experimental farm. It is an uneven piece of ground forming the compound of the Bhojpore Bungalow, and, although occasionally useful for growing crops upon, it is quite unsuited to anything in the way of exact field experiments.

At the other area near Dumraon, various experiments with manures and systems of cultivation had been attempted; but, quite apart from any criticisms which might be passed upon the experiments, it was clear to me from an examination of the surface and sub-soil that the land was too stiff a clay to form a useful experimental farm.

With good deep cultivation, clay lands have proved to be excellent in England, but it is not many years since they were shunned at home, and it is only latterly that they have been taken up. In India, generally, my experience is that clay lands are avoided as far as possible for all crops excepting rice, and I had no hesitation in recommending that another site should be selected for the Dumraon experiments, if some lighter land could be made available. This suggestion met with a ready response at the hands of the Dewan of the Raj, the late Rai Jai Prakash Lal Bahadur, who offered a piece of land of about 30 acres near the Guest House. This was found to be a level loam for the first two feet with clay underneath, and has proved so far to be much better suited to the experiments than the one formerly used.

193. *Management.*—This farm, like the one at Burdwan, is managed by one of the Assistants to the Director, a permanent overseer being in resident charge. It has always received too little attention from the Assistant Director, and, although this officer has visited it more frequently of late than formerly, four or five brief visits a year are hardly sufficient. The records are well kept and are in such a form that one can see the results of any of the experiments at a glance.

194. *Experiments at the Old Farm.*—For purposes of distinction it will be convenient to define the farm at Dumraon which was in existence in 1893 as the "Old Farm", and the land which was taken up near the Guest House in 1895 as the "New Farm".

The experiments at the "Old Farm" included the following.

195. *Experiments with manures.*—One experiment has been made on the value of bones as manure for rice and kesari on six plots (800 square yards area each); 3 were manured with bone ash and 3 were left unmanured, the crops grown being paddy in the rains followed by kesari (*lathyrus sativus*) in the cold weather, the latter being sown, as is customary, among the rice before the latter is ripe. The manured plots alternated with unmanured plots. There was, however, no object in burning the bones (for such an experiment as this) because, if there is one plant food more urgently required in India than another, it is nitrogen, and consequently, if bones are to be used at all as manure, they must certainly not be burnt.

I, therefore, recommended that unburnt bones should be employed in future. The experiment has not shown bones to be of any value at all on this land. The outturn of paddy was distinctly low on all the plots.

196. *Manures for wheat.*—Two other experiments have been made on the value of manures for the wheat crop. In one case wheat had been grown on four plots, all of which were manured with cow dung ashes, and two had a top-dressing of saltpetre in addition. In the other experiment, which included 5 plots, one plot was left unmanured and the other four were manured with bone ash: two of the latter were top-dressed with saltpetre in addition. In the case of the former I recommended that the applications of cow dung ashes should

be discontinued and the experiment converted into one to test the value of saltpetre only, which had the advantage of simplifying the issues. In the second experiment I suggested that it would become a more practical one if unburnt bone were applied instead of the burnt bone. Whilst bones have for this crop also shown themselves of no particular value as a manure at this farm, saltpetre has proved itself of considerable value.

The value of cattle dung for the sugarcane crop has also been tried at this farm, though not regularly.

197. *Implements.*—Among new implements, the iron plough is the only one which has been persistently used as a demonstration to the cultivators. It will be referred to under the next paragraph.

198. *Methods of cultivation.*—Of twelve plots, each 800 square yards area, manured alike with cattle manure, six were ploughed deep with an iron plough and six were ploughed shallow with the small wooden one, the deep ploughed plots alternating with the others.

Rice followed by *kesari* was the crop grown, and on four other plots, two of which were ploughed deep and two shallow, wheat was grown.

Like the similar experiments at the Cawnpore Farm, there has usually been a slight increase in outturn from the deep-ploughed plots, but it is not so much a question of improving the yield, but rather one of *getting the required tilth with a fewer number of ploughings,* and in this respect the experiment is of value.

199. *Methods of cultivating sugarcane.*—Experiments had been made on what is termed the "Mauritius" system of planting sugarcane.

This method has been described in paragraph 189, but as there so also here, the ridging was anything but properly done, and the value of the experiment but trivial. The error has been corrected.

200. *Experiments with new crops.*—Generally one or two crops, which have been new to the district, have been tried at this farm. Muzaffarnagar wheat has been a great success and will probably replace the local sorts. Hill potatoes will also probably prove a similar boon. The ryots are growing them in several villages, but there is a difficulty about keeping the seed from one year to the next, and experiments on this subject are being made to find out how the seed may best be kept.

201. *The New Farm.*—As explained in paragraph 192, this land was placed at the disposal of the Agricultural Department, for the purposes of experiments, by the late Dewan of the Raj in 1894. It includes an area of about 30¾ acres of nice level loam, with clay at a depth of some two feet. This is somewhat nearer the surface than one might wish; but the land is nevertheless far better fitted for experiments than that of the "old Farm". It is divided through the centre by the Railway.

During the cold weather of 1894-95 it was placed under a crop of barley without manure.

202. The analyses in the accompanying statement were made of samples taken at eight different places on this land, and they show that the soil has a very uniform composition.

STATEMENT No. 27.

Analyses of samples of soil from the Dumraon (New) Farm.

	Surface soil 1"—9".				Sub-soil 9"—2' 9".			
	Total nitrogen.	Total phospho-ric acid.	Available phos-phoric acid.	Available potash.	Total nitrogen.	Total phospho-ric acid.	Available phos-phoric acid.	Available potash.
North-half of Farm.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
North	·043	·069	·015	·013	·013	·076	·008	·006
South	·047	·066	·009	·009	·049	·071	·005	·010
East	·042	·063	·012	·010	·037	·074	·005	·008
West	·047	·099	·023	·013	·039	·084	·006	·009
South-half of Farm.								
North	·041	·081	·012	·009	·041	·065	·003	·007
South	·043	·088	·021	·010	·039	·124	·010	·009
East	·042	·077	·015	·012	·039	·067	·004	·007
West	·049	·089	·017	·015	·039	·071	·006	·010

Composition of average samples of the above.

	Surface soil.	Sub-soil.
Insoluble silicates and sand	86·73	80·78
Soluble silica	·09	·12
Iron (Fe_2O_3)	4·09	6·12
Alumina (Al_2O_3)	4·57	6·50
Manganese (MnO)	·10	·14
Lime (CaO)	·30	2·07
Magnesia (MgO)	·76	1·17
Alkalis (Na_2O, K_2O)	·48	·73
Sulphuric acid (SO_3)	...	...
Phosphoric acid (P_2O_5)	·08	·08
Carbonic acid (CO_2)	1·07	2·29
Organic matter and combined water	1·73	
	100·00	100·00
Nitrogen	·049	·041

203. Early in 1895 a programme of experiments was drawn up.

Those which it appeared desirable to commence were the following :—

Manuring sugarcane, wheat, and paddy.

Varieties of sugarcane, wheat, potatoes, paddy and some of the millets.

Deep and shallow ploughing and also one or two methods of cultivating certain crops.

When this programme was considered in detail, it was found that nearly the whole area would become occupied at the outset.

Touching this point Dr. Voelcker says in paragraph 463—

" Next it is a wise provision not to take up, at the outset, the whole of the space allotted to an experiment. As the trial proceeds, fresh issues may present themselves, which may render it desirable to add other plots to the series, or one part of the area may not be as uniform as another, and repetition of a part of the scheme may be desirable. Space for extension of the experiment in the future should, accordingly, be reserved."

It was found that, after deducting an area for farm buildings, threshing and harvesting space, and lastly pathways, only about 20 acres remained.

Accordingly the programme was drawn up in such a manner that certain sections or " blocks " of the farm would receive similar treatment, and then, whenever any of the proposed experiments should cease, not only would the past history of that particular area be known, but likewise a fairly large area would be set free at one time. Thus, for example, an area of $6\frac{3}{5}$ acres has been devoted to sugarcane experiments, all of which will be heavily manured ; and an area of $3\frac{3}{5}$ acres was devoted to paddy cultivation, most of which is manured slightly. Two blocks have been devoted to wheat, one having an area of 4 acres, the other 3 acres, most of which will be moderately manured ; for other crops, such as millets, there is an acre ; for potatoes, which also require moderate allowances of manure, there is a block of $1\frac{1}{5}$ acre (*vide* plan on page 116). Whilst, therefore, Dr. Voelcker's recommendation was not carried out to the " letter ", the principle was adhered to, and there should be no difficulty in utilising this land for future new experiments.

The experiments now include the following :—

204. *Experiments with manures.* (a) *Manures for sugarcane.*—Two series of 7 plots each ($\frac{1}{5}$ acre) are reserved for testing the value of different manures for sugarcane; a crop being taken off each series of plots in alternate years. The manures at present experimented with are cattle dung, night-soil, cattle dung and bone meal, cattle dung and superphosphate; *San* Hemp ploughed in as a green manure. It was originally intended to include both ashes of cattle dung, saltpetre and two other green manures, namely, "Tarota" and "*Psoralia Corilifolia*" in the list, but for various reasons they were given up for the time being. The two "Green Manures" named are weeds which do not appear to be common at Dumraon, and, as they are liable to spread rapidly (if allowed to run to seed), there was a risk of introducing "enemies" into the district, and thus of doing the ryot more harm than good. Moreover, before the experiments were commenced, I had come to the conclusion that there was no need to have any large number of different manures at present for sugarcane. I wished, in the first instance, to test whether phosphoric acid in large quantity is of any value to the crop and (also in conjunction with the similar experiments at the other farms) to find out the most suitable quantity of manure to apply.

With the exception of the San hemp, the manures named were therefore applied at a rate of 250 lbs. of nitrogen per acre, as indicated in the margin, quantities which I knew to be not too large to get a heavy crop. Two plots are thus left vacant for future additions to these manures. There is no unmanured plot for sugarcane at all, as it is a crop which cannot be satisfactorily grown without manure.

(1) Cow dung 250 lbs. nitrogen.
(2) Cow dung 125 lbs. nitrogen and bone dust 125 lbs. nitrogen.
(3) Cow dung 125 lbs. nitrogen and superphosphate 125 lbs. nitrogen.
(4) Night-soil 250 lbs. nitrogen (estimated).
(5) San hemp.

205. (*b*) *Manures for Wheat.*—Ten plots of $\frac{1}{5}$ acre each are reserved to test manures for the wheat crop. The list includes bones, town sweepings, dung, ashes of dung and saltpetre (all of which are applied at the rate of 50 lbs. nitrogen per acre). Ashes of the same weight of dung as is applied to the other plot, night-soil in quantity approximately equal to 50 lbs. nitrogen per acre, green manures on three plots and one "No manure" plot. The green manures suggested were *kurthi*, san hemp and *Psoralia Corilifolia*. As in the case of the sugarcane series, the latter has been cancelled for fear of its spreading to surrounding fields.

206. (*c*) *Manures for Paddy.*—For this experiment 2 sets of 4 plots ($\frac{1}{5}$ acre) are reserved, cattle dung, ashes of dung, and bone dust being applied to three plots, and one remains unmanured in each series. The idea of this experiment was simply to enable me to test whether nitrogen or phosphoric acid was the more important plant food for the crop; the corresponding experiments at Burdwan had shown that bones had been of much service, 3 maunds of bones having given as large a crop as 150 maunds of cattle dung. At Dumraon the cattle dung and bones were applied at a rate of 25 lbs. nitrogen each, and the latter would accordingly provide far more phosphoric acid than the dung, and the ashes of dung would provide practically no nitrogen, but the same amount of phosphate, as the unburnt dung. Thus on two plots no manure is applied, on two others no nitrogen but some phosphate, on two others the same amount of phosphate, and in addition 25 lbs. nitrogen, and on the fourth pair of plots 25 lbs. nitrogen and a much larger amount of phosphate.

Experiments with Varieties of Crops.

207. *Sugarcane.*—Two sets of seven plots each ($\frac{1}{5}$ acre) have been set apart in the sugarcane "block" for testing varieties of sugarcane, each set being occupied in alternate years.

Six varieties, including two local varieties *Bhurli* and *Mungo*, two varieties, *Khari* and *Samsara*, from Bengal, the Poona Pundia and a "variety" going by the name "Red Bombay" have been grown during the past year, and a seventh, a local one, named *Chun*, is to be added. The one named "Red Bombay" is of very doubtful origin, and appears to be a mixture. All the varieties are

manured alike, namely, ½ of each plot has a dressing of cattle dung, and the other ½ one of castor-cake, at the rate of 250 lbs. of nitrogen per acre. This procedure brings one very nearly within range of the criticism of involving "double issues". Dr. Voelcker in paragraph 453 writes:—

"It is not a good experiment which has a great many issues resulting from it; an experiment is not enhanced in value by reason of the many items that contribute to it, or of the many plots which are taken up in its demonstration. There should be clear and definite issues involved, and one only rather than a number."

The "double issues" in this case are more apparent than real, however. Our knowledge of the sugarcane crop is not by any means complete, and it has still to be seen what are the most suitable manures for it, and in what amounts they should be applied. I, therefore, endeavoured to place each variety under somewhat different manurial conditions, so that, if one manure happened to be better suited to a certain variety than another, this effect (which would be outside the experiment) would not escape notice.

As a matter of fact, it is fortunate that the experiment was planned in the manner indicated, for the first year's crop showed that all the varieties grew somewhat differently with the one than with the other manure, and whilst, of course, one must wait patiently for some time before drawing definite conclusions, it is probable that the several varieties are differently affected by various manures, and that consequently it is quite unsafe to take a variety of sugarcane and grow it on a plot at an experimental farm with a certain weight of manure and say "this is a fair sample of such and such a variety". The whole question, as I have said, is in its infancy, and the only thing one can do at present is to grow varieties under such conditions as may seem most suitable, and note the results.

(*b*) *Wheat.*—Ten plots (⅕ acre) have been reserved for varieties of wheat, the present list including two local sorts, one white and one red, two Muzaffarnagar varieties, a white and a red, two Punjab varieties, a white and a red, and four Central Provinces varieties, two white and two red. They are all manured with town sweepings at the rate of about 50 lbs. of nitrogen per acre. This experiment has probably yielded a definite result already.

Both rabi seasons, since the experiments commenced, have been dry ones, and no wheat has been much damaged by rust, yet in both years the Central Provinces varieties were uniformly rusted, whilst of the other varieties, those from Muzaffarnagar District suffered least, thus showing how very susceptible the Central Provinces varieties are to attacks of this disease. I think it likely that this farm may be the means, within a few years, to indicating to the Central Provinces, varieties of wheat which are less liable to "rust" than those generally cultivated.

(*c*) *Potatoes.*—Six plots (⅕ acre) have been reserved for potatoes. At present only four varieties are grown, whilst the other two plots are employed for another purpose and will be referred to under "Methods of cultivation." All six plots are manured alike with cattle dung or castor-cake at 50 lbs. nitrogen per acre. The varieties of potatoes grown at present are "Bettiah", "Gazipore", "Cherapunji" and "Naini Tal." It has been recognised, however, in connection with potatoes, that it will be necessary to devise some means, if possible, of keeping seed tubers from one harvest until the time of sowing them in the following cold weather. Some varieties appear to keep much better than others.

(*d*) *Varieties of Rice.*—Six plots (⅕ acre) have been reserved for varieties of rice.

(*e*) *Other Crops.*—On other plots 3 varieties of maize and two of *bajri* are to be grown.

208. *Methods of cultivation.*—Among experiments which fall under this category are the following:—

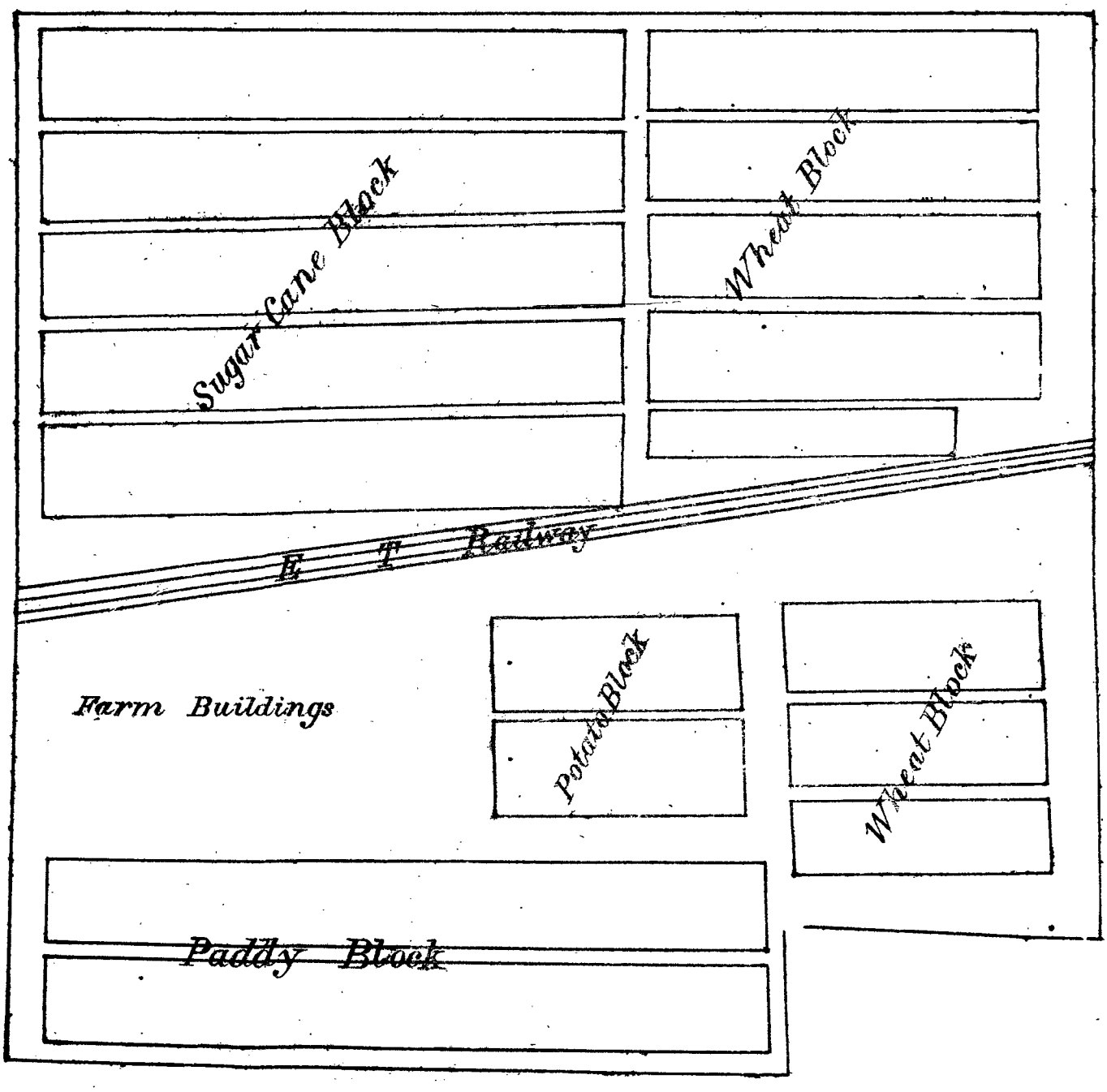
Sugarcane is planted "on the flat", as it is customary with the ryots of Behar, and also on ridges (the so-called "Mauritius" system); four plots (⅕ acre) have been reserved for this purpose. The amount of manure applied is similar to that on the other plots of the sugarcane "block".

On two plots in the "block" reserved for potatoes, this crop is grown (1) from whole tubers, (2) from cut sets. The treatment of the land is similar to that on the other plots of this "block".

In one of the two "blocks" which are at present devoted to wheat, this crop is grown without irrigation on two plots, one of which is manured, the object being to estimate the effect of cattle dung on "dry" land.

Deep *versus* shallow ploughing is tested on four ($\frac{2}{5}$ acre) plots for wheat and on four ($\frac{1}{5}$ acre) plots for rice.

Rough Plan of the Dumraon Farm



CHAPTER XI.

Agricultural Education.

209. My connection with Agricultural Education in India has been limited to that of examining the students of some of the Agricultural Schools. Thus, as a Member of the Board of Examiners in the Madras Technical Examinations, I have examined the students of the Saidapet (Madras) Agricultural College in 1895, 1896, and 1897 in Organic Chemistry and Agricultural Chemistry; in 1896 I was present at the *viva voce* examination; on the other two occasions I merely set the papers and arranged for the practical examination in Organic Chemistry.

In the same three years I personally examined the students of the Cawnpore Agricultural School, in Agriculture, and Agricultural and General Chemistry, and set the papers of questions in these subjects for the Annual Examinations at the Nagpore School. Whilst, therefore, I have not had that intimate personal experience of the students at these schools which is afforded to a lecturer, I have nevertheless had a sufficient opportunity of becoming acquainted with them and their studies to enable me to form an opinion on one or two points related to this subject.

210. *The Courses of Study.*—At Saidapet the course of study extends to three years; at Cawnpore and Nagpore to two years.

Field Work.—At all three institutions the students do a considerable amount of practical work, including ploughing and other details of cultivation and the harvesting of crops.

At Cawnpore and Nagpore, where well-managed experimental stations are maintained, the students have the additional advantage of becoming acquainted with the details of the experiments, and, what is probably still more important, realising the necessity for exactitude in the execution of these and allied experiments. At both Nagpore and Cawnpore the weighing, and, in some cases, the preparation of the produce for the market, are executed by the students. Thus, for example at Cawnpore, all the sugarcane harvesting and crushing of the cane and boiling down the juice has been done by the students.

Lectures.—In the schools, besides lectures on agriculture and allied sciences, Surveying, Analytical Chemistry and the preservation of botanical specimens are taught practically. Thus, so far as the schemes are concerned, they must be considered as being very suitable for the purpose.

211. *Text books.*—There is very urgent need of a series of good text books on Indian agricultural subjects. One or two elementary treatises have been published. Such for instance are Fuller's "Agricultural Primer," Benson's "First Book of Agriculture", and Basu's "Notes on Indian Agriculture." But these are admittedly very elementary; and many of the illustrations contained in them, are derived from European Agriculture. What is required is a much more comprehensive series of text books, each member of which should deal with one particular branch of the subject.

Even for the class of student which has been attracted to these schools up to the present, it has been necessary to supplement the text books referred to by those which have been written for use in England or America. The reason for this want of text books is doubtless two-fold. Firstly, there has been but a limited call for such books in the past, and even now there are in the whole of India but four schools of agriculture with an aggregate of some 60 or 80 students. And secondly, the number of men who have been able to devote their whole time to agriculture might be counted on the figures of one hand.

Further, it must be admitted that the amount of accurate information which we possess on the various branches of Indian agricultural subjects is extremely limited, and that very much work must be still done in this direction before a really good set of text books can be produced.

Doubtless, as the number of agricultural students increases and the demand for such a set of text books becomes more pronounced, the deficiency will be

met. For the time being, however, the absence of such a valuable aid has to be borne in mind when criticising the work done by these schools.

212. *The class of students.*—It is difficult, even for one who like myself has had several opportunities of personally examining the students at the several agricultural schools, to express an opinion on them and their qualifications, partly because they appear to be of much the same educational status at each of the schools, and partly because I have had but a very limited opportunity of judging whether, in after life, they would have been qualified to do any useful agricultural work.

Those among the students, who have obtained Government employment on leaving the schools, have in nearly all cases been drafted into the revenue service, and I think I am correct in saying that these have done no further work of an agricultural nature. Some few others of the students have been, more especially in Madras, utilised for agricultural work.

Judging by what I have seen of them, the Indian student has an unfortunate weakness for merely learning things by rote, and of caring little whether he really understands what he studies. For agricultural purposes this is a great fault. Nothing is more important in this class of work than that it shall be done intelligently, and not by "rule-of-thumb."

Otherwise the work is, as a whole, well done by the students, and it should be possible (provided they had a qualified officer to direct them) to utilise these men in the Agricultural Department in many practical ways.

At the same time, among the students whom I have examined, I am doubtful if any one would ever have qualified himself for directing the agricultural work of an entire province, and of thus capably executing the duties of "Deputy Director" or "Assistant Director" of the Department.

In paragraph 132 I have referred to the question how this office can be best filled, and, as I have there said, I believe that, whilst for the present Europeans must be employed if any useful work is to be done, still this should be recognised as only a temporary arrangement, necessitated by the fact that qualified natives are not to be had at present, and that it should be a part of the policy to try to gradually find better and better qualified natives for the agricultural work.

The majority of the students, who attend these schools, do so simply with the idea of getting Government employment. Nor can one be surprised that this is the case. They are in most cases men who have to earn their living, and unfortunately the Government is practically the only employer of this description of servant. The landed proprietors as a body are so ignorant of agriculture, and the possibility of its improvement, that they do not understand the desirability of enlisting the services of managers who have had a good agricultural training. Thus, the only employment open to an agricultural student is Government service.

In some cases, however, more especially in Madras, the sons of landed proprietors do go through the college course with a view to improve their estates, and Mr. Keess, the Principal, told me that altogether about one-fourth of the students have been of this class. So likewise at Cawnpore, a school which has only been opened within the last few years, one or two sons of zemindars have joined the school with a like object. This is to my mind the most encouraging thing that I have met with in relation to agricultural education.

213. The foregoing has reference particularly to what is at present being done. I now wish to make a few remarks as to agricultural education generally.

I have already mentioned incidentally that the number of agricultural schools in India is four, where an aggregate of some 60 or 80 students pass through a course of agricultural study.

Considering that the population (approaching 300 millions) of India is for much the greater part purely agricultural, it must be allowed that for all practical purposes there is no such thing as any real scheme of agricultural education.

I do not propose to deal with the education (of an agricultural nature) which might profitably be given to the generality of small cultivators. What I wish to refer to is the most lamentable ignorance and universal apathy of the larger landed proprietors and educated men, who live by the profits of the soil, yet know nothing of agriculture and are wholly unable to assist the cultivator in any way. At page 379 of Dr. Voelcker's report he mentions that a well-to-do landed proprietor told him "the cleverest son is sent to the law, the next into Government employ, the dullest one goes to agriculture or else to trade," and I believe that such is a correct representation of the state of the case.

It is this which, to my mind, is the real stumbling block to advancement in Indian agriculture.

It has been said over and over again that it is difficult to improve Indian agriculture. Dr. Voelcker in the opening part of chapter 2 of his report speaks of how good a cultivator the Indian ryot is; but, nevertheless, when dealing with one agricultural subject after another, he points out how little care is taken of manure, how in some parts the tillage and cultivation is far superior to what is more common, how little knowledge is exemplified of the advantages of seed selection, how badly the grass lands are cared for. Surely if this is a fair representation of the actual state of things, one cannot say for a moment that there is any difficulty in finding useful agricultural work in India?

Indeed, there cannot be the least doubt that any zemindar, who cared to take up agriculture, could set to work on any one branch he chose to specialise, and would find no lack of useful work. But, when one can count the men on the fingers of the two hands who, in the whole of this vast Peninsula, devote their time to agriculture, it is surely not surprising that no material progress is made. I am convinced that, difficult as the problem may be, what is most urgently required is to educate the sons of landed proprietors, who can afford a good education and are later in life independent, to help in this work.

It is this class who have been mostly instrumental in helping to improve European agriculture; they have organised and supported both agricultural shows and colleges, and have found the means to employ a large number of scientific workers. If the like interest could be enlisted in India, something might be done.

At present the sons of the largest landed proprietors are educated in colleges, but of agriculture they learn nothing. and, since these colleges are situated in large towns, the actual surroundings in which they are brought up are of a non-agricultural nature. Later on in life their estates are mismanaged, the owners run into debt and the properties have to be taken over by Government to save them from utter ruin. It must surely be admitted that there is room for improvement here, and that improvement, I maintain, would consist in training the landed classes to take an intelligent interest in practical agriculture and the allied sciences. There might thus be some hope that in the future the improvement of Indian Agriculture would not depend upon the one or two who might form an Agricultural Department, but on the many who are so directly interested in the soil.

Such organisations as agricultural societies would then become feasible. At present they are out of the question.

APPENDIX 1.

LIST OF TOURS.

1893.—January to April.—North-Western Provinces and Oudh.—Devoted to an examination of usar land in the North-Western Provinces, the Cawnpore Experimental Farm, and Captain Chapman's reclamation experiments.

1893.—November to December.—Bombay Presidency.—Examination of salty land on the Nira Canal, and institution of sugarcane experiments at Poona. A short tour was also made with Mr. Ozanne, Director of Land Records and Agriculture, in Gujarat, to see the general cultivation and to assist in the selection of the site for an experimental farm at Surat.

1894.—January.—Madras Presidency.—Devoted to an examination of certain localities, namely, Salem, Coimbatore, Bantanahal, Bellary, Rajahmandry, and the Kistna and Godavery Deltas, at some of which it had been proposed to institute experimental farms.

1894.—February.—Berar.—A brief visit to Ellichpur and Chikalda to examine laterite soils.

1894.—February.—Bengal.—Devoted to an inspection of the three experimental farms.

1894.—March.—Central Provinces.—A brief visit of inspection was made to the Nagpore Experimental Farm.

1894.—August to September.—A tour of inspection of the Farms at Cawnpore, Dumraon, and Nagpore. I also visited the Military Farms at Saharanpore and Allahabad.

1894.—November to December—Oudh.—Devoted to an inspection of usar land in the Unao, Lucknow, Bara Banki, and Bahraich Districts.

1895.—January.—Devoted to an inspection of the farms at Cawnpore, Dumraon, Burdwan, and Nagpore. At Cawnpore a number of analyses of sugarcane were executed.

A visit to the Wards' Estate at Gaya was also made, with a view to suggesting useful agricultural work there.

1895.—February to March.—The first half of February was devoted to analyses of sugarcane and its products at Poona. I then went to the Kaira District, Gujarat, to examine the "Oosar" land which occurs there. After this an examination of certain well waters in the Charotar was made.

1895.—April.—A brief visit to Cawnpore to examine the students at the Agricultural School.

1895.—August.—Devoted to a visit in Eastern Bengal to inspect the process of jute-steeping.

1895.—November.—Devoted to an examination of usar lands in the Karnal, Ferozepore, Lahore, and Muzaffargarh Districts, and the country bordering on the Cheuab Canal in the Punjab.

1896.—January.—Devoted to an inspection of the farms at Burdwan, Dumraon, and Cawnpore. I also attended the Agricultural Conference at Calcutta early in the month. Visits were likewise paid to Behea, to see sugarcane cultivation and the working of the Hand Centrifugal Sugar Separator, to the Allahabad Grass Farm, and the Aligarh Usar Reserves.

1896.—February.—The first half of the month was devoted to an analysis of sugarcane, etc., at Cawnpore. I then paid a visit of inspection at the Nagpore Farm.

1896.—March.—This month was devoted to analyses of sugarcane, etc., at Poona.

1896.—April.—A brief visit was paid to Madras to examine the students at the Saidapet Agricultural College.

1896.—November.—A tour was made in the Bareilly, Sitapur, Bara Banki, Gonda, Gorakhpore and Gazipore Districts, to see whether useful agricultural work could be instituted in the Court of Wards' Estates.

1896-97.—December to February.—Analyses of a number of varieties of sugarcane were made at Poona. A tour was then made in the Southern Mahratta country to examine sugarcane. I then returned to Cawnpore to examine the sugarcane at the farm, where twelve days were spent. With a similar object, visits were paid to the Experimental Farms at Dumraon and Burdwan and to Messrs. Thomson and Mylne's Estate at Behea.

1897.—April.—A brief visit was paid to Cawnpore to examine the students of the Agricultural School.

APPENDIX 2.

List of Papers and Reports.

1. Reclamation of reh or usar land (Agricultural Ledger, 1893, Nos. 12 and 13).
2. Introduction of European Dairying into India (Agricultural Ledger, 1893, No. 17).
3. Ploughing-in of green crops (Agricultural Ledger, 1893, No. 20).
4. Silage-making in India (Agricultural Ledger, 1894, No. 2).
5. Farm yard manure (Agricultural Ledger, 1894, No. 3).
6. Assimilation of Nitrogen through the agency of the root tubercles in certain *papilonaceæ*, (Agricultural Ledger, 1894, No. 7).
7. Embankments in agriculture (Agricultural Ledger, 1894, No. 16).
8. Agricultural improvements in the Gya District (Agricultural Ledger, 1895, No. 4).
9. The Nagpore Experimental Farm (Agricultural Ledger, 1895, No. 11).
10. Chemical composition of sugar and sugarcane juice and of the raw sugar (Agricultural Ledger, 1895, No. 13).
11. Well waters and soils (specially suitable for tobacco cultivation) (Agricultural Ledger, 1895, No. 14).
12. The disposal of night-soil (Agricultural Ledger, 1895, No. 16).
13. Improvements on Court of Wards' Estates in the Bara Banki District (Agricultural Ledger, 1895, No. 17).
14. The Meerut Demonstration Farm (Agricultural Ledger, 1896, No. 18).
15. Chemical composition of sugarcane and raw sugars (Agricultural Ledger, 1896, No. 19).
16. Chemical composition of sugarcane and raw sugars (Agricultural Ledger, 1897, No. 3).
17. The value of silt as a manure (Agricultural Ledger, 1897, No. 5).
18. Reclamation of reh and usar land (Agricultural Ledger, 1897, No. 7).
19. Indian manures, their composition, conservation and application (Agricultural Ledger, 1897, No. 8).
20. Note on the usar lands of India (Agricultural Ledger, 1897, in the press).
21. The composition of Indian soils (submitted).
22. The reclamation of ravine land at Allahabad (not published).
23. Notes on jute steeping in Eastern Bengal (not published).
24. Agricultural implements in India (circulated to Departments of Agriculture).
25. Note on recording and publication of results obtained at Experimental Farms in India (circulated to Departments of Agriculture).

G. I. C. P. O.—No. 431 R. & A.—21-10 97—300.—P. M M.

00110457

Digitized with financial assistance from
Shri Brihad Bhartiya Samaj
on 31 October, 2019